SCHOOL SCIENCE AND MATHEMATICS

VOL. XLVII MAY, 1947 WHOLE NO. 412

A POST CARD

FROM THE PRESIDENT

Occupying a prominent place in educational magazines this year, are the articles on teachers' salaries. The daily press and the popular magazines have publicized the situation and advocated action to an extent unheard of in the past. Apparently public opinion is more favorable toward paying salaries to which professionally trained persons are entitled than it has been in the past. While the financial difficulties of teachers along with other white collar workers may not be solved for months to come, it does seem quite possible that teachers will emerge from this period better paid than they have been at any time in the past.

If such is the case, we teachers in turn, have an obligation to furnish the highest type of leadership and service of which we are capable. Just "keeping school" should be unsatisfactory. We must know how to do the job in the best possible way. We must furnish evidence of a superior product.

Reading professional publications and attending professional meetings are the best means the busy teacher has of keeping up with trends in his profession. For science and mathematics teachers the Central Association has furnished this service and organized leadership for nearly fifty years. The fact that it has the largest membership in its history, even though other organizations have been formed more recently to which many of these members also belong, is evidence of its vitality.

Much can be gained in a short time by attending a professional meeting where you have the opportunity to hear the problems and trends in your field discussed by experts and where you can exchange ideas with fellow teachers in the section meetings and

in casual conversation. The present officers propose to make the Chicago Convention on November 28 and 29 at the Edgewater Beach Hotel as significant and valuable as those of past years. Why not start now to get your co-workers to thinking about spending two profitable days with you and hundreds of others with the same interests at the Chicago Convention?

G. E. HAWKINS

DILEMMAS OF THE SCIENCE TEACHER

BENJAMIN C. GRUENBERG

How can we teach with conviction scientific ideas that are almost certain to be superseded?

How can we teach scientific ideas that are offensive to the parents of our students or to the public at large?

How can we glorify the material achievements, or the "applications," of science while the majority of the population is still without the "common decencies"?

How can we urge the further advancement of science, which justifies itself so largely in terms of technological gains, when these gains are manifestly undermining the economic security and the spiritual health of millions?

How can we encourage scientific scepticism without endangering the idealism and the socially necessary respect for traditional order among young people?

How can we relate the science that we teach to what is being done in other scientific fields, not one of which anybody can master?

How can we teach students to adjust themselves to a social order that is both threatened by science and dependent upon science—and that is in any case destined to change?

Don't go back on "science"; find the solution through more and better science.

A 40-HOUR WEEK OR ONLY 77 HOURS?

The modern student at a metropolitan college does a much bigger day's work than does the average working man, according to a study made at The Cooper Union Schools of Art and Engineering in New York.

The average day engineering student at The Cooper Union spends 27 hours a week in classes and 30 hours a week in study. In addition, he puts in $8\frac{1}{2}$ hours a week riding subways, trains or buses getting to and from school. Then, with a couple of extra hours a week devoted to extracurricular activities, he finds $67\frac{1}{2}$ hours of his week occupied in one way or another with the business of getting an education.

The evening student of engineering has an even tougher week. Since a requisite for entrance to evening engineering at The Cooper Union is daytime employment in engineering fields related to his studies, the average night school student finds himself with a 77-hour week. Forty hours of this is at his job and 32 at his books. Probably from necessity, he's managed to cut his commuting down to five hours a week.

MARS THROUGH A SMALL TELESCOPE

JOHN STERNIG*
Glencoe Public Schools, Glencoe, Illinois

Each time Mars comes into the evening sky, telescopes of all kinds turn to it. Its surface is eagerly scanned by professionals and amateurs alike. The writer was no exception during the opposition of 1946. Since Mars again comes into the evening sky late this year it was felt that perhaps others might be interested in what can be seen on it through a telescope. This article will therefore indicate some of the results of observations during the winter of 1945–46.

The equipment used was very modest: a Bardou refracting telescope of 2-7/8 in. aperture used with a 115 power eyepiece. It had never been seriously used on Mars in previous years, since it had not seemed large enough. However, the writer determined to discover just what such a telescope could do if used persistently. Though the opposition of 1946 was not a favorable one since the planet never came closer than about 59,500,000 miles; nevertheless the results of the observations were quite enlightening. They proved that careful study under good seeing conditions allowed a small telescope to serve a most useful purpose.

The accompanying drawings will show what is meant. They do not represent the planet as it appears to one glancing casually at it, but rather what can be seen during moments of good seeing over a period of ten to fifteen minutes of intent gazing. Under such conditions the features appeared as shown, and were readily identified by reference to maps of Mars. Observations began in December of 1945 and ended in March of 1946. The drawings shown here are only a few of the many made in this interval.

In set one, drawings one and two show Mars as it appeared

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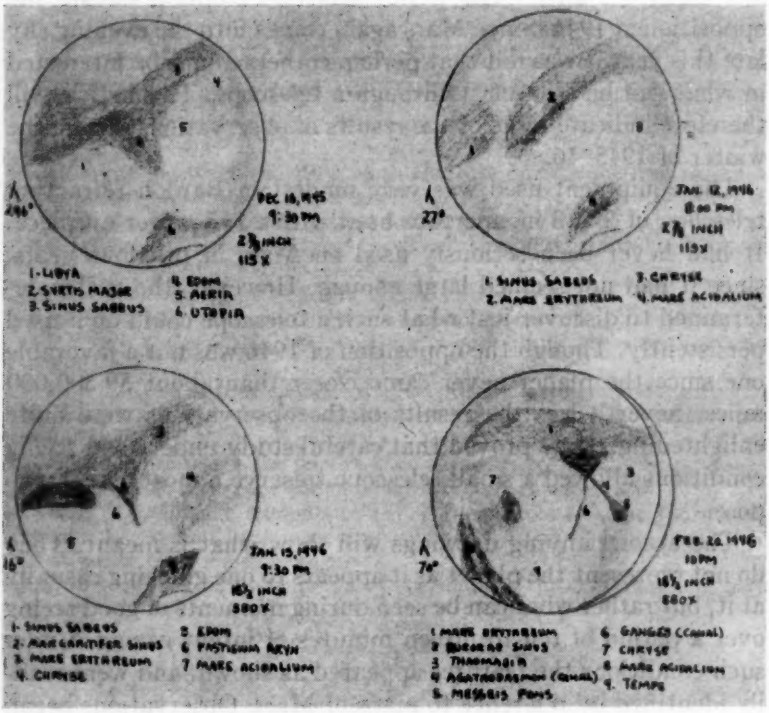
through the small telescope. For comparison, drawings three and four show the planet as seen through the large 18½ inch refractor at the Dearborn Observatory, Evanston, Illinois where the writer serves as special lecturer. The small telescope showed Mars as yellow-orange in overall color, rather than red. The dark areas appeared as plain grey. The Dearborn refractor showed a wealth of varied color with a definite overall redness



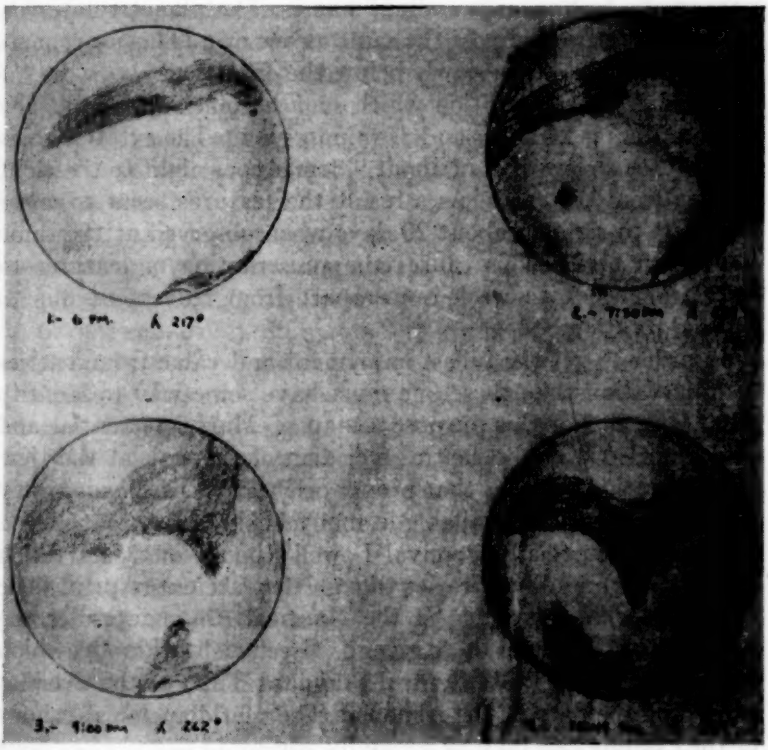
SET I

while the dark areas appeared distinctly green at times. The large telescope with its superior definition showed all the details crisply and sharp when the air was good. The small one gave a more diffused appearance to everything on the disk and demanded closer attention before things could be seen.

One of the greatest thrills came on the night of February 20, 1946 while observing with the Dearborn Refractor. Two "canals" were seen without doubt. These are indicated on Figure 4. Many more suggested themselves but were too uncertain to be

recorded. The small telescope never showed anything that could be taken for a canal.

The second set of drawings records another high spot in Mars observing. It is a record of the planet's rotation in the course of an evening. For these observations the small telescope was used throughout. Observations began at 6 P.M. with Mare Chimmerium dominating the disk. Slowly the features moved toward



SET II

the left as shown in the drawings, until by 10:45 P.M. Syrtis Major held the stage. At the pole Utopia shared the motion from right to left. The air that night was remarkably steady and gave the telescope a chance to do its very best.

At this point there should perhaps be some explanation for the benefit of those unfamiliar with Mars. More is known of the surface of this planet than any object in the sky with the exception of the moon. With its thin air and its relatively close ap-

proach to earth at time of opposition, the surface of the planet is easily studied. The features there seen are highly diversified. White areas at the poles mark the position of the polar snow caps. The major portion of the globe is composed of desert areas which are generally reddish or ochre in tint. The rest of the surface is made up of dark areas, which, in the Martian growing season appear greenish. All the areas are carefully mapped and named, hence the reference in the drawings and preceding paragraphs to "queer sounding" names. The planet rotates on its axis in a period almost the same as our own. This movement causes the disk to turn slowly before the observer.

There is another motion which soon becomes apparent. The day on Mars is 24 hours and 37 minutes long. The extra 37 minutes causes a slow drift of about 9 degrees per night to the right as seen from the earth. As a result the features seem to move from left to right in about 20 days when observed at the same hour each night. This causes the presentation of features to vary from week to week quite apart from movement due to diurnal rotation.

In order to get the fullest enjoyment and value from a series of observations like these one must have some way to identify what is seen. For this purpose a map of Mars is essential and also knowledge of the central meridian of the disk at the time of observation in order that proper orientation to the map may be found. Maps are available in many books and magazines on astronomy, especially Percival Lowell's books on Mars which may still be found in libraries though they are out of print. The central meridian is given in the Nautical Almanac under the Mars notes. The time there given is Greenwich Midnight which corresponds to 6 P.M. Central Standard Time of the evening preceding the date in the Almanac. The meridian for any hour of the evening can then be found by adding 15 degrees per hour for each hour after six to the Meridian given in the Almanac. For instance: Suppose it is 8 P.M. (C.S.T.) on Dec. 11. You wish to know the central meridian of Mars. In the Mars notes look up Dec. *12*. The meridian given there will be for Greenwich Midnight of the 12th which is 6 P.M. of the 11th. Suppose it says 250 degrees. Now 8 P.M. is two hours past 6 and since each hour equals 15 degrees you need to add thirty degrees to the 250 which makes the central meridian for 8 P.M. equal 280 degrees.

The distance of the planet is also given in the almanac for every day. Furthermore the date of the season on Mars can

easily be determined by looking up the Planetocentric longitude of the sun in the Mars tables. This can be converted into the date by referring to the sun tables for the date of the given longitude. For instance: On January 1, 1946 we find the planetocentric longitude given on page 410 is 19 degrees. On page seven we find that 19 degrees corresponds to April 10. So the date on Mars is April 10. This is interesting to know in connection with the shrinking polar cap.

Good seeing has been referred to a number of times. It should be explained that this refers to the quality of the image seen through a telescope and is determined by the condition of the atmosphere. On a night when the air is unsteady the telescope magnifies this unsteadiness along with the object being observed. The result is a blurred, unsteady image in even a fine instrument. When this condition persists there is nothing to do but pack up and go indoors. There is nothing to be gained from such observing except eyestrain and annoyance.

Fine details on Mars require the very best condition of seeing. The writer found only 30 nights out of about 120 which were good enough to allow drawings to be made. Furthermore, observations with a small telescope are profitable only in the month or so preceding and following opposition. Before or after this time the planet is too far away for much to be seen. During this interval however, the writer found that even a small telescope is capable of showing enough detail to make observations worthwhile and interesting.

The remarks in this article have been limited largely to matters of observing. No attempt was made to get into debatable issues concerning theories and speculations. That is a matter distinct from simple observing and gets us into fascinating fields which had best be left for another time.

THE WELFARE OF THE NATION IS AT STAKE

The United States dare not forget the nations are only as strong and as great as their people. We cannot long neglect our public educational system and expect to maintain our place of leadership in the world; to continue as leaders in science and industry; to free ourselves from ignorance, prejudice, and hate cults; to build a higher standard of living for all; to preserve our way of life as a free people.

This country is amply able to support its schools. The national income increased 300 per cent from 1932 to 1944 while school expenditures increased only 12 per cent.

Since the future of this nation depends first of all upon the development of human resources, continued financial neglect of public education can lead only to national disaster.

IMPROVING THE QUALITY OF INSTRUCTION IN MATHEMATICS

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The philosophy underlying all education has perhaps been studied and considered with care by all teachers or prospective teachers, but it is the purpose of this paper to recall and emphasize some of the most important aspects of education, and to give some suggestions for improving mathematical instruction in particular

Perhaps the most generally accepted aim of education is the preparation of students for good citizenship. It becomes necessary to define good citizenship. It is taken for granted that a citizen must be honest, law-abiding, and prepared to make his own living. Economic and material well-being are essential, but are they sufficient? Does man live by bread alone?

Teachers of mathematics have had to face the charge that algebra, geometry, and higher branches of the subject do not contribute to the needs, chiefly economic and commercial, of many students. It is perhaps true that many teachers of mathematics have failed to make full use of the value of their subject, not only in its economic and material aspects, but also in its power to widen the student's mind and to bring about true education in its broadest, most really beneficial, aspect. The part that mathematics can play in a liberal education by developing the intellectual resources of the students has been sorely neglected in recent years, due largely to materialistic elements in our culture. Given enough rope, this materialism may yet hang itself—the atomic bomb suggests that.

Materialism and economic efforts must be guided by reason or intellect. The development and improvement of the intellect has been put forth as one of the chief purposes of education by the wisest men throughout history. In education, Aristotle and Plato gave prominence to instruction in mathematics. Plato saw that mathematics was a practical help in industry and war, but he valued it chiefly for its role in developing the intellect and the power to think. Aristotle likewise found much value in mathematics, and it is in connection with his philosophy of moral and intellectual virtues—a philosophy which still underlies the beliefs of many millions of people—that assistance can

be derived for the justification and encouragement of mathematics in our system of education. Aristotle said:

> But the virtues we get first, by performing single acts . . . . Men come to be builders by building, and harp-players by playing on the harp; in the same way exactly by doing just actions we come to be just, by performing the activity of self-mastery we come to be perfected in self-mastery, and by doing brave deeds we come to be brave . . . . Or, in one word, the habits are produced from the acts of working like to them.

In other words, we develop our ability to think and to reason only by thinking and reasoning. Now, despite any arguments *pro* or *con* on the theory of formal discipline, at least that much will be admitted by practically all educational philosophers. Then we must find and teach those subjects which give practice in thinking and reasoning. No one will deny that mathematics is such a subject *par excellence*. If any person doubts the relative value of study in mathematics as compared with that in some other subject, he should observe the faces of students who are trying to solve a problem in mathematics, and compare their expressions with those of students in a class listening to a speech or tale given by a classmate or to a lecture by a teacher. One look at both types of classes will be convincing evidence of the educational value of mathematics in aspects which are of greater ultimate value than merely acquiring information.

The importance of intellectual development is finely stated in the words of John Henry Newman:

> There are men who embrace in their minds a vast multitude of ideas, but with little sensibility about their real relations toward each other . . . . When this analytical, distributive, harmonizing process is away, the mind experiences no enlargement . . . . If they are nothing more than well-read men, or men of information, they have not a liberal education.

Newman might well have been thinking about a problem in algebra or a demonstration in geometry when he said:

> That only is true enlargement of mind which is the power of viewing many things at once as one whole, of referring them severally to their true place in the universal system, of understanding their respective values, and determining their mutual dependence.

Newman's ideas about the true meaning of education should be considered by the proponents of "soft pedagogy":

> Recreations are not education; accomplishments are not education. Do not say, the people must be educated, when, after all, you only mean amused, refreshed, soothed, put into good spirits and good humor, or kept from vicious excesses. I do not say that such amusements, such occupations of mind, are not a great gain; but they are not education. You may as well call drawing and fencing education, as a general knowledge of botany or conchology. Stuffing birds or playing stringed instruments is an

elegant pastime, and a resource to the idle, but it is not education; it does not form or cultivate the intellect.

Technologists tell us that in the future we shall have much more leisure than now. What will people do with this unoccupied time if they are to escape mischief and boredom? Surely some sort of intellectual development must pave the way for the happiness even of successful tradesmen and workers. And the wise functioning of our society must depend upon the intelligence of the general public. The part which mathematical training can take in developing such general intelligence and liberal education should be recognized by all, and by mathematics teachers especially.

The above comments and citations should give the mathematics teacher new and stronger faith in the value of the subject. They should make it possible for every teacher to sell himself and his subject to all the students, even to the 80 or 90 per cent who may never go to college or use algebra, geometry, and higher branches of mathematics on a specific job. We are engaged in teaching people to think and to reason, and this is a very important work.

Specific Suggestions for Improving Instruction in Mathematics

1. The teacher must be enthusiastic and dynamic. The value of mathematics in practical and thought-provoking situations should be kept in mind at all times. If the teacher really feels that the lesson or assignment will contribute to the student's material and intellectual benefit, this feeling will spread to the entire class. A sound understanding of educational philosophy and aims, such as those set forth by Plato, Aristotle, Newman, and others of the present time, should produce enthusiasm for learning and teaching mathematics. But a teacher cannot sell a subject or a topic which he or she does not personally believe in strongly.
2. Be human—realize the natural inclination of boys and girls to do things instead of reading about them, to develop their bodies before their minds, and to live and act in the concrete, visible, material world rather than in the abstract, theoretical, and ideal world.
3. Admit to the pupils that brain-racking study, or almost any kind of intellectual endeavor is contrary to primitive minds and against the grain of human nature. Then show them that

our present highly developed society demands this intellectual development and self control, and that if they do not want this civilized life, they should consider the life of a Hottentot or a savage, who is not burdened with modern education.

4. Constantly keep before the pupils the principle that character development and training in morals, civic duties, and intellect, is equally important with "book learning," and that doing the daily assignments, being neat and accurate and reliable, and following the rules of the school, all help to develop good character.
5. Specific suggestions for improving techniques and practices in the teaching of mathematics are:
   a. Be sure that the students can read the textual material and comprehend it.
   b. Grade and return as much of the assigned homework as possible.
   c. Give frequent tests, using them not only as measuring devices but also as teaching exercises.
   d. Start the class promptly and in a business-like manner.
   e. Talk with enough volume and sufficient emphasis to make the class realize the work is important and to enable them to discover the purpose of the lesson at hand.
   f. Walk around the room, along the back and the sides, to make sure that all students have books, pencils, paper, etc., and that all are attending to the instruction. This will prevent some wayward children from wasting time, reading comic books, drawing funny sketches of various persons (often the teacher, perhaps) and letting the teacher's directions go in one ear and out the other.
   g. Try not to talk too much. See that the pupils listen to directions or read them in the textbooks, and then start acting according to those directions in solving problems or exercises.
   h. Have as much work done at the blackboard as possible. A student at the board has to be awake and attentive, at least, and learns better than if seated, in many instances. Many students enjoy working at the board.
   i. See that the students sit up straight and avoid slouching.
   j. Always plan the lesson so that everything is completed before the bell rings at the end of the period. Students become very nervous watching the clock at the last min-

ute, just like their older brothers and sisters and parents do in offices and factories. The students are only human, too; don't expect too much of them; don't be a taskmaster.

k. Try to be cheerful and optimistic at all times.

FINDINGS IN SCHOOL SURVEY

1. Three hundred and fifty thousand teachers have left the American public schools since 1940.
2. One hundred and twenty-five thousand teachers, or one out of every seven in the profession, are serving on an emergency or sub-standard certificate.
3. Seventy thousand teaching positions are unfilled because of the inability of communities to get the necessary teachers.
4. Sixty thousand teachers in the United States have a high school education or less.
5. Twenty per cent of all teachers, or 175,000, are new to their jobs each year—twice the turnover that existed before the war.
6. Classroom teachers get an average of $37 a week today. Two hundred thousand get less than $25 weekly.
7. Fewer students are entering the teaching profession than in the past. Twenty-two per cent of all college students attended teachers' colleges in 1920; today 7 per cent attend.
8. Veterans do not want to prepare to teach. Only 20,000 of the 1,000,000 veterans in American colleges and universities are in teachers' colleges.
9. Six thousand schools will be closed because of lack of teachers; 75,000 children will have no schooling during the year.
10. Two million children will suffer a major impairment in their schooling because of poor teachers.
11. Five million children will receive an inferior education this year because of the inadequate teacher supply.
12. Only 50 per cent of the teachers employed in 1940–41 are still teaching today.
13. The average teacher in the United States today has had one year less education than she had in 1939.
14. Fifty thousand men have left the teaching profession since 1940, and are not coming back. Only 15 per cent of all elementary and high school teachers are men.
15. Twelve major school strikes have taken place since September—and many more are being threatened.
16. The morale of the teachers has dropped to a new low.
17. Fifty-six per cent of the teachers of this country do not have tenure protection.
18. The United States spends 1.5 per cent of its national income for its schools. Great Britain spends an estimated 3 per cent; the Soviet Union spends 7.5 per cent.
19. Appalling educational inequalities exist throughout the nation. Top schools spend $6000 per classroom unit, bottom ones spend $100. The national average is $1600.
20. School buildings are in a deplorable state all over the nation. Nearly five billions dollars will be needed to bring the educational plants into good condition.

—*New York Times*, 2/20/47

SOME SIMPLE WAYS OF DEMONSTRATING CHEMICAL PRINCIPLES

ROBERT H. LONG
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Seeing a scientific principle being applied as well as having it described is accepted as being of the greatest importance to the learning process. Demonstrations are often by-passed because of the lack of expensive apparatus, or because the teacher does not have the time to assemble elaborate set-ups for showing a principle at work. Simple means of showing a principle can sometimes be worked out using the common items of a laboratory.

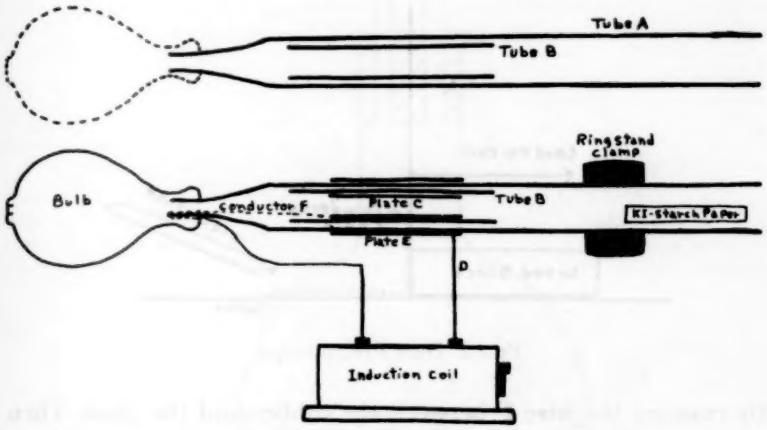

FIG. 1. Ozone Generator.

The actual demonstration, even if very simple, is more important to the student than the quality of the apparatus involved. The following demonstrations are suggested to other teachers because they have been found to be easy to prepare and require very little time for setting them up for use.

A SIMPLE OZONE GENERATOR

An apparatus for demonstrating the principle of ozone preparation and showing the oxidizing property of the substance can be easily made as shown in Fig. 1. The apparatus can be set up quickly and requires little storage space.

The materials needed for constructing the device include: Glass tubing as specified, thin copper sheeting, copper wire, an

atomizer bulb and an induction coil. Note: A high frequency vacuum tester is an excellent piece of equipment to use in place of an induction coil in class demonstrations.

The apparatus is made as follows: Draw out one end of a piece of glass tube, that is between 1.5 and 2 centimeters in diameter and of sufficient length to form a finished tube about 30 centimeters long, to a diameter suitable for attaching the atomizer bulb as shown by A. Next cut a piece of glass tubing, of smaller diameter, about 10 centimeters long as shown by B. Roll a piece of sheet copper into a cylinder, to which fasten fine copper wire as shown by F, and place this in the smaller tube as shown by C. This assembly is placed inside of the large tube and the plate C is connected to one terminal of the induction coil

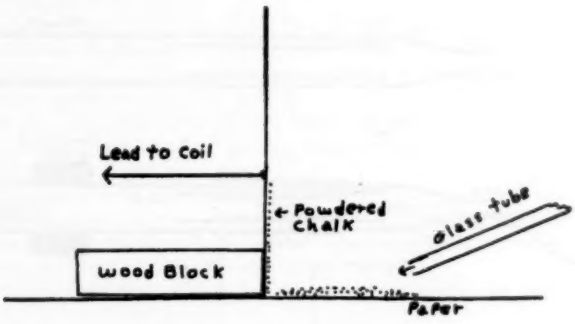

FIG. 2. Dust Precipitation.

by running the wire F between the rubber and the glass. Then cut a second piece of the copper sheeting and fit it around the outside of tube A as shown by E. Connect this plate to the other terminal of the coil. When clamped to a ring stand the apparatus is ready for operation.

A moistened strip of potassium iodide-starch paper is placed in the open end of the tube as shown. With the electric discharge taking place across the plates, pump air through the device. The test paper will quickly turn blue. By forcing this ozone-air mixture through a delivery tube attached to the open end of the apparatus a stream of the gas can be used to show other interesting examples of the oxidizing property of this gas.

DUST PRECIPITATION DEMONSTRATION

The principle of smoke and dust precipitation can easily be demonstrated as shown in Fig. 2 This is done by mounting a

metal plate on a wooden base (to also serve as an insulated handle) and placing this on a sheet of paper. Chalk dust is then sprinkled in a thin layer in front of the plate. While high voltage is being applied to the plate, by an induction coil or vacuum tester, blow some of the chalk dust gently toward it by means of a long section of glass tubing. The powder, representing dust, will be attracted to the plate.

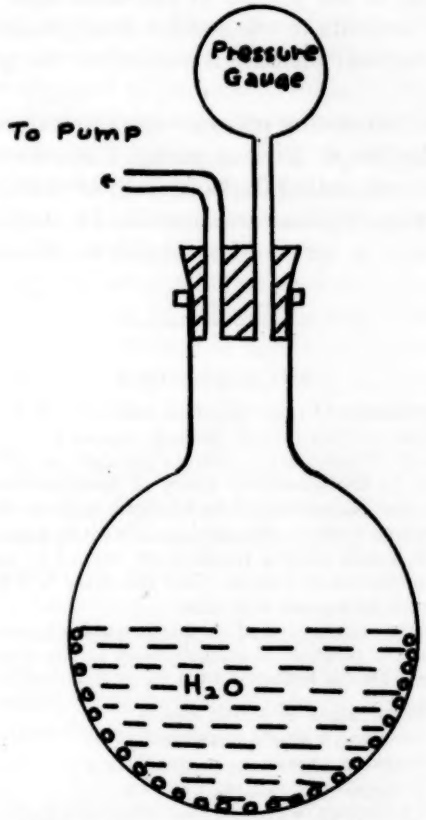

FIG. 3. Effect of Pressure on the Solubility of a Gas.

THE EFFECT OF PRESSURE ON THE SOLUBILITY OF A GAS

During the study of solutions the effect of pressure on the solubility of a gas in a liquid can be easily demonstrated in a qualitative way as shown in Fig. 3. Some cold tap water is placed in a flask and the latter fitted with a stopper containing a connection by rubber vacuum hose to a filter pump. If a vacuum gauge is at hand it may be attached as shown to actu-

ally indicate what changes in pressure are taking place. However, the experiment can be very meaningful with out this instrument.

Start the filter pump and have the students observe the formation of bubbles on the inside of the flask between the wall and the water. After a heavy layer of large bubbles has formed stop the pump and then very slowly loosen the stopper, or the hose connection, to the pump. At the same time direct the attention of the students to the sudden disappearance of most of the bubbles as normal pressure is restored to the space above the water.

Note: Many interesting pressure demonstrations can be performed with the simple filtering pump. Extreme care should be exercised when evacuating flasks in front of students, even with a filter pump, as such glassware sometimes is shattered. It would be better to have a safety-glass shield for demonstrations of this type.

MICROBIOLOGY

Visual science, offers a 35 mm. Slidefilm which will solve one of the most perplexing problems of Health and Biology teaching.

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THE CRISIS IN SCIENCE AND MATHEMATICS TEACHING

RALEIGH SCHORLING
The University of Michigan, Ann Arbor, Michigan

Who is going to teach science and mathematics in our high schools in the years just ahead? That should be the number one question in the minds of all thoughtful citizens. We will no doubt manage to get persons labeled emergency teachers into most science classrooms as caretakers of our youngsters. But what about the poor quality of teaching? That is the alarming threat to the welfare of our children, to the strength of this nation, and to the future of the world.

There is no need to recite in detail the facts picturing the drastic shortage of teachers in all fields of the high school. They have been recently hammered home in official government statistical reports, and in a dozen popular magazines, as for example, *Good Housekeeping*. The public at long last is alarmed. Politicians, ever quick to gear their speeches to popular thinking, do not make many speeches these days without a plea for a square deal for teachers. It is significant that Harold E. Stassen, when announcing his candidacy for the presidency, outlined a brief platform of four planks, of which one is to increase the salaries of white collar workers—especially teachers. Even the top flight radio comedians, as for example, Parkyakarkus, Fred Allen and Bob Hope seem to be alarmed about our vanishing teachers. Now that the salary of the school teacher is a grim joke we may be able to do something about it.

What's happening to our teachers? Many teachers of experience are leaving their classrooms. We are told that New York City alone lost 1000 during the last 12 months. In the war years competent teachers—especially science and mathematics— were useful in many branches of the Armed Forces. They learned that they were good at other jobs offering larger salaries, lighter work and greater freedom.

It is bad enough to have so many experienced teachers quitting but there is a far more disturbing fact: ***young persons are rejecting teaching in the lower schools as a career.*** This year nearly all colleges and universities are overflowing, but only a few per hundred are planning to teach. Last semester there were about

200,000 students enrolled in 24 prominent colleges and universities* that educate teachers. This list includes state universities like the Univeristy of Minnesota and large teacher colleges as for example Greeley and Peabody. Note that these 24 schools had about 1/10 of the 2 million students in our 1749 higher educational institutions. In these 24 institutions there were last semester only about 2200 students doing practice teaching—a course that all must take to qualify for the elementary and secondary schools. The number electing practice teaching this semester is no doubt much larger. Nevertheless the total number of students qualifying for the certificate this year in all institutions will be a small fraction of the 200,000 well qualified new teachers that we should have next fall.

What is the picture in these 24 schools as regards future teachers of science and mathematics for the high schools? In this vast student body of 200,000 there are only 450 who will this year qualify for the certificate in science and mathematics! My own school, the University of Michigan with more than 18,500 students, is perhaps typical. We have only 26 students—some not too strong—who will this year qualify in physics, chemistry, biology, general science or mathematics. The total number of student teachers in physics and chemistry for the year is 4; two of them with majors in chemistry, one with a minor in chemistry, and one with a minor in physics. Note that we do not have a single student with a major in physics who is planning to teach in high school.

The other large schools in our state present the same discouraging picture. Michigan has seven tax supported educational institutions that educate teachers. There are at present over 53,000 students in these seven schools—over 1/40 of all students in higher education in the country—but there are only about 1300 who will some time during this year take practice teaching in an elementary grade or in some high school subject. There are 128 students among the 53,000 that will this year qualify as science teachers, including mathematics! Since there are more than 200,000 students in Michigan high schools study-

* Purdue University, University of Michigan, Eastern Illinois State Teachers College, Indiana State Teachers College, Michigan State College, New York State College for Teachers, New York University, George Peabody College for Teachers, University of Alabama, University of Iowa, University of Oregon, University of Southern California, University of Wisconsin, University of Nebraska, University of Virginia, Iowa State College, Greeley Teachers College, University of Kentucky, Indiana University, University of Washington, University of Connecticut, University of Kansas, Leland Stanford University, University of Minnesota.

ing science and mathematics we need at least twice as many teachers of science as we now have in training and many, many more if we were to replace teachers with emergency certificates and the incompetent.

If we assume that our two samples as regards future teachers of science are typical of the whole population in higher education—2 million—one may venture the guess that we probably have only five or six thousand students in the whole country who will this year qualify as high school teachers of science and mathematics! We need at least twice this number to insure a good quality of science teaching.

The number of undergraduates majoring in science or mathematics and doing graduate work in these fields is probably a higher per cent of the total enrollment than it was ten years ago—certainly this is true at the University of Michigan. In 19 of these institutions with a total enrollment of about 150,000 there are at least 5000 undergraduates majoring in science and mathematics. In 18 schools with an enrollment of about 140,000 there are at least 2000 graduate students specializing in science or mathematics. But they are not at present qualifying to teach science or mathematics in the high school. Ohio State University reports that it has 913 graduate students in the sciences including mathematics. It is not likely that as many as 50 will ever teach in high schools, or that 10 will ever teach secondary school mathematics. The young men in science are attracted so early by industry that they do not even bother to qualify for the teacher's certificate.

At the rate that industry, business and government are now picking up young scientists wer have no assurance that a high fraction of these 450 seniors doing practice teaching in science in these 24 training schools will be teaching science or mathematics in high school next fall.

The October 1946 number of *Fortune* prints a dramatic interview between Mr. Marshall, president of Raytheon, and a brilliant young physicist from MIT. The physicist asked what he would be expected to do at Raytheon. Whatever you like! He asked how much he would be paid. Whatever you like! The story, though a bit exaggerated, suggests the opportunities in industry for young men trained in science. The beginning salaries in some cases may be about the same. But the life expectance of total earning is several times as great for the young scientist in industry as in classroom teaching of science.

We may note in passing that the outlook for enough good teachers in every high school field with the possible exception of physical education and music is dark. In the elementary grades it is hopeless in the years just ahead. Of the very small number of seniors in all our training schools who are taking the courses to qualify for the teachers' certificates, many will not even start teaching .The majority of women in this group will almost certainly quit before the end of three years. Keep in mind that young men nowadays have money for marriage early in life. The type of young woman who used to teach—in many cases quite effectively—for about three years, now is likely to get married within a year of her graduation from college. The stream of young people that used to flow into the teaching profession has just about dried up.

Don't count on the veteran to teach in high school. To be sure there are some veterans who taught before the war and who will stay in the teaching profession. But they are for the most part in graduate courses in education. Nearly all are mature men disciplined by heavy responsibilities who are definitely planning to be administrators, supervisors, college teachers, and technical workers. Moreover, they could not support their families on the low salaries that are now offered to them as classroom teachers. The University of Michigan alone has about sixty veterans who are planning to go all the way to the doctor's degree in professional education. They will, no doubt, be grand school men. But as teachers of your children, you might as well write them off your books. Of the million veterans now in school probably less than 18,000 will actually teach in high school unless they are driven to it by a future depression.

The problem of getting and holding men teachers in high school is becoming alarming. Men rejected teaching in the elementary school as a career long before the war. Today there are very few men teachers in the early grades of any large school system in the country. There is convincing evidence that men teachers are now disappearing from our high schools. Witness the fact that there are only seven men in a group of 96 students now doing practice teaching at the University of Michigan. Of these, one will enter the medical school next fall, one wants to be an agricultural agent under civil service, one is hoping to be a director of community recreation, one has an eye on Broadway, one will enter the graduate school, and one is planning to teach in a junior college. Only one lone man in this group has the fixed

purpose of teaching in high school! Many thoughtful parents would like to have their children taught by a staff of which a third, or even a half are men teachers. Under existing conditions that will not be possible.

There is another cloud in the sky which should cause us concern. We have had a big increase in the birth rate during the war years. In the four year span, 1937 to 1940 inclusive, we had only about 9.1 million births, whereas in the 4-year period, 1941–44 inclusive, we had a little over 11 million. We had almost 2 million extra babies! Nor is the birth rate dropping as some believe, for it turns out that 1946 set an all time high. We have only a very few years to get ready for a wave of tots that will roll in on us in the form of a much larger enrollment in the early grades. Then we will need many additional teachers—certainly 50,000, which is far more than the number of young people now in training who will actually go into the elementary grades. In fact we have less than 48,000 women in our 201 teachers colleges and normal schools who were enrolled in college before last fall. The problem will reach the science and mathematics departments in the high school about nine years hence.

By that time we are told we will have a critical shortage of young scientists. Persons who know best are estimating that we now have a deficit of 5700 Ph.D's in science and this is expected to become 15,000 by 1950. Dr. Karl T. Compton estimates that we will need about 90,000 new engineers by 1950. Colleges and universities with their huge enrollments and the junior colleges now undergoing phenomenal expansion will beg industry and government in vain not to rob them of research workers and science teachers. We in the high school field may stand on the side line, watch the ruthless fight over good material and take shoddy leavings for teachers of high school science.

This, then, is the dark, hopeless picture throughout the country—it is true for your state and for mine. Where will we find enough good teachers? Unless we take certain definite steps, we probably will not find them.

The question is, what can we do? The answer, of course, is make teaching attractive to our youth. How can we make teaching a desirable profession for the students in our high schools and colleges? By taking out of the picture those things that now cause youth to turn away from teaching.

Let's look at some of their reasons. Consider first the matter of salary—not because it is the most important factor but because

it is the one that can get public action quickly enough to help us in the immediate future. So much has recently been printed on the gap between the salaries of teachers and those in other lines of work that little need be said here on that point.

The favorite stunt in magazines and on the radio is to contrast the salary of a school teacher with that of the dog catcher, the rat exterminator, the garbage collector, the bartender, the elevator operator, the cotton picker, the janitor and maintenance man. Most well-informed persons are now probably aware that industrial workers in a typical town, if they do not lose wages through strikes average from $800 to $1000 per year more than the classroom teachers. They know that when a teacher's salary is contrasted with plumbers, painters, carpenters and technical workers in industry who need to devote three or four years to training for their job, that the gap is much wider—perhaps as much as $2,000 per year in favor of the technical worker. However, they might be amazed if they made a study of the situation in their own community and discovered that about a fourth of their teachers get less than the commonest of common laborers.

How does the teacher with a family manage to live? The answer is by taking part-time jobs on top of a double load. For example *Time* December 23, 1946 reports that $\frac{3}{4}$ of the men and $\frac{1}{4}$ of the women in a group of 3500 teachers polled in New York City were doing side-line work to get along. Amazingly enough one teacher of the *social studies* gets a salary of $51.25 a week and $60 a week for tending bar in part-time hours. He is quoted as saying that bartenders now discuss teacher salaries as "something terrible." Even principals of large high schools are driven to neglect their great responsibilities by taking an outside work to support their families.

The teaching profession includes an astonishing number per hundred who labor with high competence and missionary zeal regardless of compensation. For that we are grateful and proud, but a million persons do not year after year give themselves to any calling without appropriate salary. What really happens as has been suggested is that many of our best prospects for teaching are attracted by better paid jobs in industry, in commerce, and in the other professions.

Shameful as the salary situation is, there are about a dozen additional reasons why young people are choosing other fields of work. Most of these relate to the working conditions of teachers. It will be a fatal mistake if we assume that we can get and keep

enough good teachers merely by doubling the salary of every teacher. When editors, columnists, cartoonists and comedians champion the cause of our teachers, salary and social status naturally are important. Basic as these matters are, we nevertheless will not come to grips with the problem of attracting enough young people of the right kind without adequate consideration of one other factor. In an earlier day affluent persons had slaves, governesses, and servants to aid them with such menial tasks as drawing water, hewing wood, and caring for children. Today most homemakers are better off in that they can turn on the faucet, set the thermostat and send the children to school. Any mother who takes care of three or four restless youngsters all day is weary by night and any father who has been so reckless as to try it is a wreck by noon. Yet a teacher who does far more than take care of children is expected to work with a roomful of children hour after hour.

There are about 12 things that need to be corrected. These were listed in a document entitled "An Evolving Bill of Rights," first published in 1945. Since this statement has been republished in more than 40 journals and used as a basis in articles and editorials in several hundred newspapers and magazines we need do no more here than to list the rights as follows:

1. The right to teach classes that are not too large, in general from ten to twenty pupils.
2. The right to have time in the school day for planning.
3. The right of a 45-hour week.
4. The right to adequate compensation for the full year of fifty-two weeks.
5. The right to an adequate amount of helpful and constructive supervision.
6. The right to have good materials and enough of them.
7. The right to work in a room that, with the help of the students, can be made pleasant and appropriate to the tasks to be learned.
8. The right to the same personal liberties which other respectable citizens assume for themselves as a matter of course.
9. The right to an internship.
10. The right to a realistic program of in-service education.
11. The right to participate in changing the curriculum and methods, and in formulating school policies.
12. The right to keep from being lost in the profession.

Obviously, any school board that sets up decent working conditions will have to spend more money for schools. The writer has seen many schools, but never a good one that did not cost a

lot of money. There is no greater fiction abroad than the notion that the American people have been generous in the financial support of their schools. Any nation that spends more per year for chewing gum than for instructional materials and whose annual expenditure for education is only $\frac{1}{2}$ as much as for liquor, only 3/10 as much as for cosmetics, only $\frac{1}{6}$ as much as for its Army and Navy in this, a year of peace, and only $\frac{1}{5}$ as much a for the care of criminals and delinquents is obviously not too much concerned about the education of its youth. Many parents interpret the phrase "free schools" to mean free as the air at the gas station. Some parents pay more to sitters who take care of their children for a few hours in the evening while the youngsters sleep than they do to the teachers who toil with the restless youngsters throughout the wearying day.

How shall we get the money that we need to create good schools? By gearing the financial support of education to our economy. It should be a fixed per cent of our national income. The rate should be scientifically determined and the total amount for education should vary with our national income and with the purchasing power of the dollar. It is not sensible for us to pay without much complaint nearly 5 per cent of our national income for education in times of depression and then recklessly allow our schools to deteriorate by spending only 1.6 per cent of our income in prosperous times.

We must spend at least one-half as much for schools as we do in the care of criminals and delinquents. Then we can add a million additional teachers and thus end the futile expectation that each teacher do the impossible job of two persons; then we can improve working conditions of the teachers and thus make teaching a challenge and an inspiration; then we can take steps to give due recognition to the gifted teacher and thus differentiate the professional worker from the mere transient; then we can attract the best of our young people and thus comb out the incompetent teachers with weak personalities that now downgrade what should be a great profession; then we can hold a reasonable number of men in both the elementary and the high school grades; then we can insure that a reasonable number of the teachers of our children—let us say half of them—will be really good; then we can feel confident that this nation will continue to grow strong in its influence for a better world.*

* Some of the facts given in this paper were previously published in *The Science Teacher*, February 1947, in an article entitled "Recruiting and the Economic Status of the Science Teacher."

AN IDENTIFICATION AID WHEN DISSECTING FROGS

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The adult frog, in high school biology, is the animal most frequently used for study of the internal organs of vertebrates. Observing and stressing these anatomical structures is important when laying a basis for understanding body functions. Average secondary students, however, have little background which will enable them to realize maximum value from their dissection work. If this work is done, it should be a component of the science learning process. Having completed a dissection, the student should be able to identify each organ and compound it with a body activity. To aid his students in the proper identification of the internal anatomy of their frog specimen, the

FIG. 1. Internal Organs of Frog

1. Heart—Circulatory.
2. Lungs—Breathing and Respiration.
3. Liver—Secretes bile.
4. Gall bladder—Stores bile.
5. Stomach—Digestion.
6. Pancreas-Digestive gland.
7. Spleen—Destroys old blood corpuscles.
8. Kidneys—Excretory.
9. Intestine—Absorption.
10. Bladder—Excretory.
11. Cloaca—Passageway to external of body.

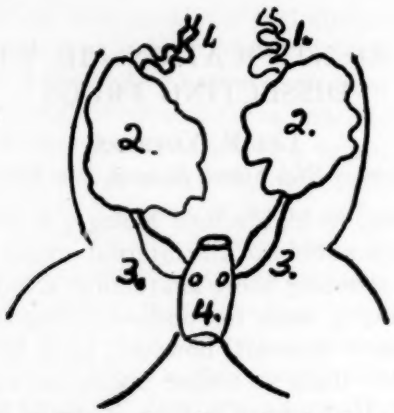

FIG. 2. Female Frog Reproductive System

1. Oviduct—Duct from ovary.
2. Ovary—Egg cells produced.
3. Uterus—Egg passageway.
4. Cloaca—Common passageway for excretory and reproductive systems.

FIG. 3. Male Frog Reproductive System

1. Fat bodies—Store up nutrient.
2. Testis ducts—Passageway for sperms.
3. Testis—Sperm cells produced.
4. Ureter—Common passageway for liquid waste and sperms.
5. Seminal vessicle—Sperms stored.
6. Cloaca—Common passageway for excretory and reproductive systems.

writer has them follow the procedure which is outlined below.

A stencil is prepared, showing three diagrammatic drawings of the frog. Included are the organs sketched in their approximate body position with a number assigned to each. A corresponding number is written in the margin, followed by the name and use

of the organism. Mimeograph copies are made available in sufficient number for individual issue. A glance at the drawings which follow will clarify this part of the preparation.

Having the drawings before them, the student's attention is called to the different organs to be identified and, also, their function. With this background, the internal organs are exposed. As each structure is removed, it is placed on the proper position of the drawing. When the dissection is completed an examination is made by the instructor to determine whether all the organs were found and identified. Later, the students study the individual parts.

During the past years, the writer has tried a variety of methods to make dissection work of significance to the young people he teaches. This approach has proven the most effective with his secondary students.

AWARDS FOR RESEARCH

Pi Lambda Theta announces two awards of $400 each, to be granted on or before August 15, 1947, for significant research studies in education.

An unpublished study may be submitted on any aspect of the professional problems and contributions of women, *either in education or in some other field.* Among others, studies of women's status, professional training, responsibilities and contributions to education and to society, both in this country and abroad, will be acceptable.

No study granted an award shall become the property of Pi Lambda Theta, nor shall Pi Lambda Theta in any way restrict the subsequent publication of a study for which an award is granted, except that Pi Lambda Theta shall have the privilege of inserting an introductory statement in the printed form of any study for which an award is made.

A study may be submitted by any individual, whether or not engaged at present in educational work, or by any chapter or group of members of Pi Lambda Theta.

Three copies of the final report of the completed research study shall be submitted to the Committee on Studies and Awards by July 1, 1947. Information concerning the awards and the form in which the final report shall be prepared will be furnished upon request. All inquiries should be addressed to the chairman of the Committee on Studies and Awards.

Bess Goodykoontz, U. S. Office of Education,
Washington D. C., *Chairman*

OINTMENT PREVENTS BURNS

An antiflash burn ointment that may prove useful to industries such as steel mills where radiated heat is a hazard has been developed by the Chemical Corps, formerly the Chemical Warfare Service, in co-operation with the Navy. At the recent Bikini atom bomb tests, bomb flashes which charred the paint on certain ships failed to injure the skin of animals, on the same ships, protected with the ointment.

COMPUTATIONS WITH APPROXIMATE NUMBERS

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The *Third Yearbook* published by the National Council of Teachers of Mathematics in 1928 gave considerable space to such topics as "Direct Measurement," "Measurement and Computation," and "Use of Measuring Instruments." Since 1928 many excellent articles on "How to Compute with Approximate Numbers" have appeared in magazines and in secondary and college texts. Then in 1937 The National Council of Teachers of Mathematics devoted its entire *Twelfth Yearbook* to "Approximate Computation." In spite of all this effort most students are still being graduated from our high schools with the impression that all numbers are exact and that computations involving such numbers, if properly done, result in exact numbers.

This exact number complex is so deeply ingrained in the thinking of most high school graduates that for anyone to dare to suggest to them that many perfectly good numbers are only approximate either marks the informer as an ignoramus or it undermines the student's faith in the whole structure of mathematics. This is an unfortunate situation. The best solution for it appears to be a renewed emphasis on the teaching of approximate numbers and elementary approximate computations, both in the mathematics and science classes, beginning not later than the first year of the junior high school and continuing throughout the secondary school period.

The ability to count was one of man's earliest accomplishments. When indivisible units are counted and stated as a certain number that number is said to be exact; this means absolutely precise, or 100 per cent perfect. If the daily attendance at a movie theater is reported as 2,567, it means exactly 2,567 people; if a farmer counts and finds that he has 27 cows and 56 sheep, he means just that; and if you count and find that you have $7.58 in your wallet, you mean exactly that amount. Of course, it follows that computations with exact numbers, correctly performed, produce exact results. If 25,000 people buy football tickets at $3.00 each, the amount is $75,000.00. This $75.000.00 is the count of an indivisible unit, the dollar, and is an exact number. It cannot be changed in any way. Let it be

agreed then that numbers obtained by counting indivisible units will always be considered to be exact.

Numbers which represent measurement; numbers obtained from tables of logarithms, of natural trigonometric functions, the American Air Almanac and many similar tables; numbers derived from convergent series; and a vast array of numbers, such as pi and epsilon, will always be considered approximate numbers. That pi, the number of times the diameter of a circle is contained in its circumference, is an approximate number might be shown by recalling that Shanks, an ambitious Englishman, worked out this number to 707 places and still never reached absolute accuracy. It is evident then that pi expressed to five digits, that is 3.1416, is an approximate number.

Of course one should never think of an approximate number as one that has been carelessly obtained. An approximate number does not mean that at all. Rather it means one that does not express absolute precision. It is the record of a number to a certain degree of accuracy. Likewise one should never think of computation with approximate numbers as computation carelessly done. The rules given in this paper will produce the best possible answers from the given data. The data and not the computation are approximate. In the field of measurement there never has been such a thing as an exact measurement of such concepts as weight, time, angles, temperature, length, area, volume, and the like. Tremendous efforts have been made to obtain absolute standards of measurements but, short of the possibilities of light wave lengths, no perfect measurements have ever been made. For the time being we are, therefore, obligated to continue to teach that all numbers which represent measurements, as well as many other numbers, are approximate numbers.

Much confusion has been brought about by the loose manner in which the terms commonly employed in the discussion of approximate numbers have been used. This is especially true as regards such terms as accuracy, precision, and correctness—computation correctly performed and the answer correctly rounded. In an attempt to alleviate such confusion every effort will be made in what follows to make terms such as units of measurement, significant digits, accuracy, degree of accuracy, possible or apparent error, precision, percent or relative error, etc., mean exactly what they should mean in this discussion of approximate numbers.

Units of Measurement

The unit of measurement is the smallest unit used in making a measurement. If a tea cup were used to measure the water placed in a coffee percolater the unit of measurement would be the tea cup; if the hand were used to measure the height of a horse, the hand would be the unit of measurement; and if an unmarked stick one foot long were used to measure the length of a concrete wall the foot would be the unit of measurement. Good practice in dealing with approximate numbers is to state the units of measurement involved. If, however, the unit of measurement is not stated the most sensible thing to do is to assume and use the least precise unit implied by the given data.

To say that the distance to the sun is 93,000,000 miles is a very indefinite statement. Does this mean that the distance has been measured to the nearest mile, the nearest thousand miles, or to the nearest million miles? The safest unit of measurement to use for the distance as stated is 1,000,000 miles. On the other hand, assume that the measurement for the edge of a book is expressed as 5.9 inches. In this case the implied unit is very clearly 0.1 inch. This unit of measurement of 0.1 inch means that the edge of the book has a length of 5.9 ± 0.05 inches. It is recorded as 5.9 inches, but the true measurement may be anywhere between 5.85 and 5.95 inches. Should the measurement of the edge of the book be given as 5.92 inches, a unit of measurement of 0.01 inch is implied and the true measurement is somewhere between 5.915 and 5.925 inches. Such procedure can be repeated as long as a smaller unit of measurement can be found. It follows, as will be brought out again later, that the smaller the unit of measurement used for a given quantity the more accurate will be the result.

Table I shows the units of measurement implied and the minimum and maximum limits for certain measurements.

Table I

Measurement	Implied Unit of Measurement	Limits
25,000,000 mi	1,000,000 mi	$25{,}000{,}000 \pm 500{,}000$ mi
8,756 gal	1 gal	$8{,}756 \pm 0.5$ gal
43.8 lb	0.1 lb	43.8 ± 0.05 lb
23.57 gr	0.01 gr	23.57 ± 0.005 gr
1.0470 oz	0.0001 oz	1.0470 ± 0.00005 oz
7 0/8 in	1/8 in	$7 \pm 1/16$ in
37°4′25″	1 sec	$133{,}465 \pm 0.5$ sec

Significant Digits

One should clearly understand what is meant by the expression "significant digits" because it is a ***count*** of these digits that furnishes one of the best methods of describing the accuracy of approximate numbers.

In considering approximate numbers in general, if all the digits except the last one in a number are correct, and if the error in the last digit is not greater than one-half the unit of measurement used, then all the digits in the approximate number are significant.

The digit zero may or may not be significant. For example, in a length of 8 feet, with a unit of measurement of 1 foot, the 8 has meaning and is said to be significant; in a length of 80 feet, with a unit of measurement of 1 foot, both the 8 and the 0 serve as counters and are therefore significant. If the length of 80 feet is recorded and the unit of measurement is stated as 10 feet, then the 8 means that there are 8 of the given units in the total length of 80 feet; the 0 to the right of 8 is not a significant digit, but it must be present as a place marker. It appears therefore that zeros may or may not be significant.

The contents of Table II below will be discussed in an effort to make understood just when, or when not, zeros are significant.

Table II

Measurement	Implied Unit of Measurement	Total of Units	Significant Digits	
			Actual	By Count
A) 105.06 gr	0.01 gr	10,506	1, 0, 5, 0, 6	5
B) 2570 bu	10 bu	257	2, 5, 7	3
C) 0.0050 mm	0.0001 mm	50	5, 0	2
D) 46.0 gal	0.1 gal	460	4, 6, 0	3
E) 1.008 cc	0.001 cc	1,008	1, 0, 0, 8	4
F) 3,467.21 ft	0.01 ft	346,721	3, 4, 6, 7, 2, 1	6

Zeros are significant:

1) When they fall between digits that are significant, either in integers, mixed numbers, or decimal fractions, see Table II *A* and *E*;
2) When they are to the right of a significant digit in a decimal fraction, see Table II *C*.
3) When they are after the decimal point in a mixed number, see Table II *A*, *D*, and *E*.

4) When they serve as counters of the unit of measurement used, see Table II *A*, *C*, and *E*.

Zeros are not significant:

1) When they serve as place-holders only, see Table II *B* and *C*;
2) When they serve only to locate the decimal point, see Table II *C*.

Zeros may or may not be significant:

1) When they are to the right of significant digits, but to the left of the decimal point, see Table II *B*. In the number 2570 from Table II *B*, the zero is not significant because the unit of measurement is 10 bushels. If the unit of measurement had been 1 bushel, the zero would have been significant. When the numbers used in problems have ambiguous zeros, the author should always state the unit or the number of significant digits thus removing the ambiguity.

Accuracy

It is important to understand clearly that the accuracy of a measurement is determined strictly by the number of significant digits involved in the approximate number. The position of the decimal point in a number has nothing to do with the determination of its accuracy.

Consider the following four measurements each of which possesses the same four significant digits:

1) 235,700 feet with a unit of measurement of 100 feet;
2) 2,357 feet with a unit of measurement of 1 foot;
3) 23.57 feet with a unit of measurement of 0.01 foot;
4) 0.2357 feet with a unit of measurement of 0.0001 foot.

Because each of the preceding numbers contain four significant digits—2, 3, 5, 7—each number possesses four-digit accuracy regardless of the fact that there exists considerable variation in the location of the decimal point in the numbers.

If two numbers to be compared were 23,570 with a unit of measurement of 10 feet, and 23,570 with a unit of measurement of 1 foot, the first measurement would contain four significant digits and four-digit accuracy while the latter would possess five significant digits and five-digit accuracy. The second measurement is therefore considered to be the more accurate one.

A necessary condition that approximate numbers possess the same digit accuracy is that they possess the same number of

significant digits. An approximate number containing $N+1$ digits is more accurate than one containing N digits.

Degree of Accuracy

It is not very discriminating merely to be able to state that one approximate number is more accurate than another. Thus an expression called the "degree of accuracy," which means 100 per cent minus the per cent error, is used to state the accuracy of an approximate number on a per cent basis. The real need for expressing degree of accuracy is indicated in the two examples which follow:

A measurement of 20 feet with a unit of measurement of 10 feet;

A measurement of 6 feet with a unit of measurement of 1 foot.

Both of the preceding measurements possess one-digit accuracy but in actuality the second measurement is approximately three times more accurate than the first one. The purpose of "degree of accuracy" is to show such differences.

Several examples showing the degree of accuracy of measurements will be presented in Table IV which follows the discussion of relative and per cent errors. In the two previous examples as well as in the examples in Table IV it should be observed that if two approximate numbers possess the same number of significant digits, the digits not being identical, then the number having the largest left-hand digit is the most accurate.

Possible or Apparent Error

A measurement of 26.0 feet implies that the distance was measured to the nearest 0.1 foot and that the true measurement lies somewhere between 25.95 and 26.05 feet. The 0.1 foot is interpreted to mean that the measurement may be in error not more than 0.05 foot in either direction from 26.0 feet. Because no digit should be omitted that is known to be correct, and because no more digits should be retained than are known to be correct, all measurements between $26.0+0.05$ feet and $26.0-0.05$ feet should be recorded as 26.0 feet. From this practice of splitting the unit of measurement into two equal parts has come the concept of possible or apparent error—an error that is never greater than one-half of the unit of measurement used.

When the unit of measurement for a problem is taken as 100 feet the possible or apparent error is 50 feet; for 1 pound the

possible error is 0.5 pound; for 0.001 gram the possible error is 0.0005 gram. See Table III for additional examples.

Precision of Measurement

The precision of an approximate number is determined by the size of the unit of measurement employed. The smaller the unit of measurement used the more precise is the result.

The point has now been reached where one essential difference between the accuracy of a number and the precision of a number may be emphasized. As previously stated, the accuracy of a number depends upon the number of significant digits involved and is not in any way affected by the position of the decimal point. The preciseness of a number depends entirely on the location of the decimal point.

The accuracy and precision of many numbers increase together. However, to show that this is not always the case consider the data in Table III where the accuracy of the given measurements does not change but the precision of the numbers consistently increase.

Table III

Measurement	Implied Unit of Measurement	Significant Digit Accuracy	Possible Error	Precision of Measurement
312,540 ft	10. ft	5	5. ft	5. ft
31,254 ft	1. ft	5	0.5 ft	0.5 ft
3,125.4 ft	.1 ft	5	0.05 ft	0.05 ft
312.54 ft	.01 ft	5	0.005 ft	0.005 ft
31.254 ft	.001 ft	5	0.0005 ft	0.0005 ft

Table III indicates these facts:

1) The size of the unit of measurement is indicated by the location of the decimal point;
2) The precision of each number is evaluated in terms of its possible error;
3) The smaller the unit of measurement the more precise is the measurement.

Per Cent Error—Relative Error

The terms per cent error and relative error are found to be used interchangeably in the literature of approximate numbers. However there is a distinction between these terms that should

not be overlooked. Relative error is a ratio of the possible error of a measurement to the measurement itself. Per cent error is the relative error expressed in per cent form, that is, with a denominator which is always 100. If in measuring the top of a concrete dam 200 inches wide an error of 1 inch is made, then the relative error is 1/200 while the per cent error is expressed as 0.5 per cent.

Table IV records the "per cent errors" of certain selected measurements and the corresponding "degrees of accuracy"—it previously having been discussed that degree of accuracy of a number is 100 per cent less the per cent error.

TABLE IV

Measurement	Implied Unit	Precision	Significant Digits	Relative Error	Per Cent Error	Degree of Accuracy (Per Cent)
A) 1 mi	1 mi	0.5 mi	1	0.5/1	50	50
B) 90 lb	10 lb	5 lb	1	5/90	5.5	94.5
C) 0.10 gr	0.01 gr	0.005 gr	2	0.005/0.10	5	95.0
D) 990 gal	10 gal	5 gal	2	5/990	0.55	99.5−
E) 10.0 qt	0.1 qt	0.05 qt	3	0.05/10.0	0.5	99.5
F) 999 kg	1 kg	0.5 kg	3	0.5/999	0.05	99.9+
G) 1,000 tons	1 ton	0.5 ton	4	0.5/1,000	0.005	99.95
H) 999.9 bu	0.1 bu	0.05 bu	4	0.05/999.9	0.0005	99.99+

Besides showing the relationship of relative error, per cent error, and degree of accuracy, Table IV further demonstrates the following facts:

1) Measurements, such as *A* and *B*, which contain the same number of significant digits—that is, have the same place accuracy—differ in degree of accuracy. See also *C* and *D*, *E* and *F*, and *G* and *H*.
2) Of any two approximate numbers containing the same count but not the same significant digits, such as is shown in *A* and *B* or *E* and *F* in Table IV, the approximate number having the larger left-hand digit is the more accurate;
3) Any approximate number containing one significant digit—which means one digit accuracy—has a "degree of accuracy" of 50% or above; two significant digits, a "degree of accuracy" of 95% or above; three significant digits, 99.5% or above; and four significant digits, 99.95% or above.

Rounding Off Numbers—Effect on Accuracy and Precision

The common tendency of most computers is to retain more digits in numbers used in the computations, also in the results, than is justified by the original data. Probably the basic reason for this is that computers do not know how many digits should be retained. Consequently they feel compelled to use all the digits given in the numbers and to state the final result with far greater accuracy than the original measurements warrant. Such computations waste both time and energy.

Suppose a problem is to find the circumference of a circle with a radius of 5.6 feet. Because the first 19 of the 707 known digits in pi are 3.141 592 653 589 793 238 is no sensible reason for using all 19 of these digits in solving for the circumference. Even 3.141592 is too accurate to be used here. Under multiplication of approximate numbers, which will be discussed later, it will be shown that the original data justifies using only 3.14 for pi in the computation of the circumference of the circle in question.

"Rounding off" a number is the process of dropping digits from the right end of a number. The digits dropped are replaced by zeros *only when* it is necessary to do so to keep the decimal point in its proper place. Rounding off a number may be performed by one of the following rules:

1) If the digit to be dropped is less than 5, the digit on its immediate left which is to be retained should not be changed;
2) If the digit to be dropped is 5 or greater, the digit on its immediate left which is to be retained should be increased by 1;
3) If several digits are to be dropped from a number and the left-hand digit of those to be dropped is less than 5, the digit on its left which is to be retained should not be changed; if the left-hand digit of those to be dropped is 5 or more, the digit on its immediate left which is to be retained should be increased by 1.

Thus 3.141592 rounded to 6 significant digits is 3.15159;
3.141592 rounded to 5 significant digits is 3.1416;
3.141592 rounded to 4 significant digits is 3.142;
and 3.141592 rounded to 3 significant digits is 3.14.

Rounding off a number is certain to have some effect on its original accuracy and precision. Table V presents a few examples to demonstrate the effect of rounding off data on the accuracy and precision of the original numbers.

TABLE V

Measurements		Implied Unit	Significant Digits	Precision	Degree of Accuracy (Per Cent)
Original	Rounded				
27.573 m		0.001 m	5	0.0005 m	99.99
	27.6 m	0.1 m	3	0.05 m	99.8
36 m		1 m	2	0.5 m	98.6
	40 m	10 m	1	5 m	87.5
19,694 m		1 m	5	0.5 m	99.99
	20,000 m	10,000 m	1	5000 m	75.

In an effort to comprehend the meaning of the "rounded" column in Table V one might wish to ask why the original data, which was evidently measured to ± 0.5 of the units of measurement implied in the original numbers, should be rounded off at all. Numbers are rounded for several good reasons, two of which follow:

1) The original numbers may be too accurate to meet efficiently the purpose which they are to serve;
2) Rounding off the original numbers in a problem situation to one digit each provides a means of easily and quickly securing an estimate of the solution to the problem.

Sufficient data is presented in Table V to justify the following two conclusions:

1) The effect of rounding any number always implies a unit of measurement larger than the original one thus making the rounded number less precise than the original;
2) The effect of rounding any number decreases the significant digits and thus the accuracy of the original number is dedecreased.

COMPUTATIONS WITH APPROXIMATE NUMBERS

Results obtained by computing with approximate numbers are bound to be approximate. This simply means that when numbers from logarithmic, trigonometric, and many other tables, transcendental numbers, measurements, and a vast number of other approximate numbers are used in computations the results obtained are always approximate. How to record such results so that they will fall within acceptable limits of accuracy will now be considered.

Addition of Approximate Numbers

It certainly does not add any significance to a number used to represent the average length of twelve different kinds of automobiles to measure a Cadillac to the nearest tenth of a foot and a Ford to the nearest thousandth of an inch. The recommended practice is to take the several measurements, either of the same object or of different objects similar as to type, to the same degree of precision. In other words the fundamental rule in measuring is to

Use the same unit of measurement for all measurements in a set.

One can understand how different units of measurement might be used in measuring like objects when the measurements are made by different individuals in different localities. However,

When measurement involving different units of measurement are to be added the sum should claim no greater precision than the least precise of the measurements.

It is much harder to understand why some "standard tests" and many text books call for the addition of data involving numbers which vary greatly in their precision. There would be less reason to object to this practice if even the results obtained from such additions were expressed to the same degree of precision as the least precise number used in getting the result. Would any sane person measure the four sides of a field as 247 feet, 415.5 feet, 621.47 feet, and 725.689 feet and then add to obtain a perimeter of 2009.659 feet? The sum 2009.659 infers that the unit of measurement for all the measurements was 0.001 of a unit. The actual unit of measurement for the 247 feet was 1 unit, not the 0.001 unit indicated by the sum. To infer a unit of measurement for 247 that is 1000 times more precise than the actual unit of measurement is misleading, ridiculous, and dishonest.

The procedures for the addition and subtraction of approximate numbers, as presented in this paper, will be based strictly upon the criterion of precision.

Rules for adding approximate numbers, whether or not the given numbers possess the same precision of measurement, are developed from a study of Table VI. The A columns in the table are supposed to be original measurements to the degree of precision indicated. The B columns represent the maximum possible values obtainable from the A columns no matter how pre-

cise the unit of measurement used. The measurement of 11 feet appearing at the head of each column, being the least precise number present, is used without change in each column for the purpose of fixing the precision of the sum of the column.

TABLE VI

Case I		Case II		Case III	
Given Data	Maximum Values	Given Data	Maximum Values	Given Data	Maximum Values
A	B	A	B	A	B
1) 11 ft	11 ft	1) 11 ft	11 ft	1) 11 ft	11 ft
2) 10.1	10.19	2) 10.11	10.119	2) 10.111	10.1119
3) 10.1	10.19	3) 10.11	10.119	3) 10.111	10.1119
4) 10.1	10.19	4) 10.11	10.119	4) 10.111	10.1119
5) 10.1	10.19	To	To	To	To
6) 10.1	10.19	96) 10.11	10.119	996) 10.111	10.1119
7) 10.1	10.19	97) 10.11	10.119	997) 10.111	10.1119
8) 10.1	10.19	98) 10.11	10.119	998) 10.111	10.1119
9) 10.1	10.19	99) 10.11	10.119	999) 10.111	10.1119
91.8	92.6	1001.78	1002.76	10101.778	10102.776
92	93	1002	1003	10102	10103

Case IA shows that the minimum possible sum of the given data, obtained by rounding the numbers to the units place, is 91. Including the tenths place, adding, and rounding the sum to the units place gives 92. Moving to Case IB, rounding the maximum possible values to the tenth place, adding, rounding to the units place gives 93. Thus the sum for the nine measurements obtained by including the tenths column and rounding to the units column is not more than one unit away from either the minimum or the maximum value. Consequently the generalization:

To add nine or less approximate numbers, round all numbers to the digit to the right of the final digit to be retained before adding, then round the sum one place. The error will not exceed one unit in either direction.

Case IIA in Table VI suggests that 99 measurements are to be added. These numbers rounded to the tenth place and added give 1000.8 or 1001 when rounded to the units place. If the numbers are rounded to the nearest hundredth and added the sum is 1001.78 or 1002 to the units place. Moving to Case IIB, rounding the maximum possible values of each number to the hundredth place, adding, the result is 1002.76 or 1003 to the units

place. Thus another generalization:

To add more than 9 or less than 100 approximate numbers, round all numbers to the second digit to the right of the final digit to be retained before adding, then round the sum two places. The error will not exceed one unit in either direction.

By similar analysis Case IIIA Table VI shows that when the numbers are added to the hundredth place and rounded the sum is 10,101; to the thousandth place, added, and rounded, 10,102; and considering maximum values under Case IIIB to the thousandth place, adding, and rounding the sum is 10,103. Hence a third generalization:

To add more than 99 or less than 1000 approximate numbers, round all numbers to the third digit to the right of the final digit to be retained before adding, then round the sum three places. The error will not exceed one unit in either direction.

The generalizations arrived at from studying Table VI indicate that any desired degree of precision may be obtained by continuing the analysis demonstrated under Cases I, II, and III, that is,

To add columns containing 10^{N-1} or less than 10^{N} numbers where N is any integer above zero, round all numbers to the N^{th} digit to the right of the final digit to be retained before adding, then round the sum N places. The error will not exceed one unit in either direction.

Should it be necessary to have the final digit of the sum correct rather than to allow a possible error of one unit in either direction, it will then be essential to round all numbers to the $N+1$ digit to the right of the final digit to be retained—if the sum of the $N+1$ digit ends in 5 then to the $N+2$ digit—before adding, then add and round the sum either $N+1$ or $N+2$ places according to which one was used in the addition.

Subtraction of Approximate Numbers

In subtraction of approximate numbers, as in addition, a unit of measurement more precise than the one implied by the given data should never be used. Therefore the remainder resulting from a subtraction process should be expressed to the same degree of precision as the least precise number used in getting the remainder.

If one wants the remainder expressed to a certain selected digit the following rule is acceptable:

To express the remainder to a certain digit round off both given numbers—if necessary—to the first digit to the right of the final digit to be retained, then subtract and round the remainder one place.

Multiplication of Approximate Numbers

If the area of a rectangular plot of ground 30.5 feet long and 20.5 feet wide is recorded as 625.25 square feet, then common sense again has failed to function. The unit of measurement used for the sides does not justify the refinement of measurement expressed in the number which represents the area.

The long side of the rectangle could have varied from 30.45 feet to 30.55 feet, the short side from 20.45 feet to 20.55 feet. If the measurement had been 30.45 feet and 20.45 feet, the minimum possible lengths, the minimum area would have been 622.70 square feet. If the measurements had been 30.55 feet and 20.55 feet, the maximum possible lengths, the maximum area would have been 627.80 square feet. All one can be sure of is that the true area of the rectangle falls somewhere between 622.70 and 627.80 square feet. Since there is 5.1 square feet between the possible limits there certainly is no justification in expressing the computed area of 625.25 square feet any more accurately than the nearest square foot.

It should now be observed that the 625 square feet which is to be accepted as the most probable area contains the same number of significant digits as the original linear measurements. This observation suggests a very dependable procedure to follow in the multiplication of approximate numbers—one in which the last digit retained has been found to be significant approximately 80 per cent of the 121 possibilities.

1) *To find the product of two approximate numbers each of which have the the same number of significant digits, retain the same number of significant digits in the product as are in either factors;*
2) *To find the product of two approximate numbers one of which contains more significant digits than the other, round off the more accurate factor until it contains one more significant digit than the other before multiplying, then round the product until it contains the same number of significant digits contained in the less accurate factor.*

As previously stated an exact number differs from an approximate number in that an exact number represents a true count; it has a possible error and a relative error of zero; it is 100 per cent accurate. To state that 6 is an exact count means that the 6 is exact to a thousand, a million, a trillion, or any finite number of significant zeros. Therefore the number of significant digits in an exact number always exceeds the number of significant digits in the most accurate approximate number. Thus

3) *To find the product of an exact number and an approximate number, retain in the product the same number of significant digits contained in the given approximate number.*

Example:

Rule 1)	72.34	Rule 2)	4.76|23	Rule 3)	75.426 Approximate
	86.40		5.4		6 Exact
	289360		1904		452556
	43404		2380		
	57872				
	62501760		25704		
	6,250		26		452.56

If a solution to a problem demands that more than two factors be multiplied, find the product of two factors, round this partial product to one more digit than will be retained in the final answer, use this rounded product with a third factor to find a new product, continue the procedure until all the factors have been used, and then round the final product to contain the same number of significant digits presented in the least accurate factor.

Division of Approximate Numbers

Procedures for use in the division of an approximate number by an exact number, and of two approximate numbers, are similar to those discussed under multiplication. They are covered by the following three directives:

1) *To find the quotient of two approximate numbers, each of which has N significant digits, divide the indicated dividend by the divisor until the quotient has N+1 significant digits, and then round the quotient one place;*
2) *To find the quotient of two approximate numbers, one of which has N and the other more than N significant digits, round off the more accurate number until it has N+1 significant digits, divide the indicated dividend by the divisor until the quotient has N+1 significant digits, and then round the quotient one place;*
3) *To find the quotient of an approximate number with N significant digits and an exact number, divide the indicated dividend by the divisor until the quotient has N+1 significant digits, and then round quotient one place.*

Examples:

	0.58		21		6.949
	0.577		20.6		6.9485
Rule 1)	9.7)5.6	Rule 2)	2.3)47.5\23	Rule 3)	7)48.64
	4.85		46		
	750		150		
	679		138		
	710				
	679				

Square Roots of Approximate Numbers

The square of the approximate number 25.7, when properly rounded according to rules for multiplying approximate numbers, is 660. To reverse the process the square root of 660 is 25.7. Thus the square root of a number contains the same number of significant digits as the given number. Generalizing this idea:

To extract the square root of an approximate number with N significant digits carry the result to N+1 significant digits, and round the answer one place.

Examples:

3.29	14.18
3.286	14.177
)10.8	)201.1

Angular Measurement in Computation

In discussions of approximate numbers there is a tendency to write in terms of measurements of lengths only. The equally important concept of approximate angles usually gets no attention at all or insufficient attention. If computations involving angles were merely a matter of applying the fundamental operations to the angles the procedure already discussed would be sufficient. This is not the case. For example in the study of the triangle in trigonometry is is a matter of computations wherein certain approximate angles of the triangle are associated with certain approximate lengths. This problem is entitled to some attention.

Tables of natural trigonometric functions are used to solve for the unknown sides and angles of a triangle. The ratios in these tables are approximate numbers expressed as unending decimals. If the table used is a three-place table the last digit in the numbers seldom represents the true value; it merely is the best approximation to the true value. This is equally true for a five-place table, a ten-place table, or a N-place table. Consequently computations in which the natural trigonometric functions are used can not be more accurate than the table used in the computations.

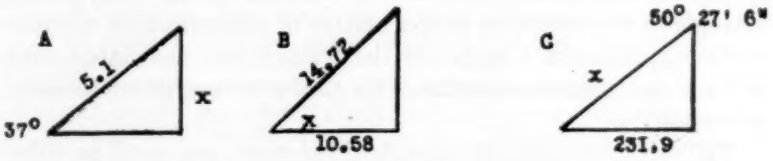
Table VII is presented as a record of the results obtained from a study of the ratios of the sine and cosine functions, for angles from 0° to 90°, as listed in a six-place table of natural trigonometric functions. It of course is evident that a change of 1° of angle usually changes the second digit in the ratio more than 1

unit. However it never changes it as much as 2 units. To be sure, the expressed relationships between the measurements of length and angles are not strictly proportional but they fall within the limits of good practice and are very simple and easy to apply to computations.

TABLE VII

Angle Measured to Nearest	Number of Significant Digits to be Retained in Ratio
5°	1
1°	2
10′	3
1′	4
6″	5
1″	6

Table VII is reversible. If the unit of angular measurement is known the proper number of significant digits to use in the ratio is indicated. Or if measurements of the sides of a triangle are given, these measurements lead to ratios which contain the same number of significant digits possessed by the sides, and these ratios then suggest the proper precision of angle to be used. Examples:



$$\frac{x}{5.1} = \text{Sin } 37° \qquad \text{Cos } A = \frac{10.58}{14.72} \qquad \text{Sin } 50°27'6'' = \frac{231.9}{x}$$

$$x = (0.60)(5.1) \qquad \text{Cos } A = 0.7194 \qquad x = \frac{231.9}{0.77109}$$

$$x = 3.1 \qquad A = 44°3' \qquad x = 300.78$$

$$x = 300.8$$

Example C differs from A and B in that the given angle suggests that five significant digits should be used in the ratio even though the given distance was measured only to four significant digits. In all cases similar to C let the given angle indicate the number of significant digits to use in the ratio, and then round off the computed distances to the same number of significant digits as was given in the least accurate side.

Conclusion

The number system is used most everyday by everybody in a dual role: as exact numbers when groups of objects are counted; as approximate numbers when numbers represent measurements, when rounded, and when taken from most tables. As a usual thing computations with exact numbers must be carried out in complete detail. The only reasonable and efficient and sensible way to compute with approximate numbers is to apply the procedures for computations with approximate numbers herein discussed; they reduce time, save unnecessary labor, and give results that fall within the limits which bound the true answer.

The present status of accomplishment strongly indicates that the most important thing is to begin the instruction in computation with approximate numbers not later than the seventh grade. The procedures should be made to function in high school and college courses in a manner that will assure that they will function, naturally, in the business of living.

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Two-eye viewer of two-inch square photographic slides enables both eyes to be used in examining a single transparency, and gives three-dimensional effect. It somewhat resembles ordinary binoculars without forward lenses, but with a transparent front and a slot for the film.

Fire extinguisher for early flames, a carbon dioxide apparatus weighing only 12 pounds, has a trigger release opened by grasping two handles like those on pliers. An elongated horn at right angles to the top directs and concentrates the discharged gas on the flame.

SCIENCE ACTIVITIES CONTRIBUTE TO PERSONAL DEVELOPMENT*

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An important aim of science teaching is to contribute to an enriched life through the development of adjustment factors in children. Since our society is becoming increasingly more complex, the child, in order to make effective adjustment in society, must relate functional knowledge to the experiences at hand. No other field offers as great an opportunity for personal adjustment and development as science.

From the child's first beginning in science activities, he uses elements of the scientific method of work, habits of thinking, and ways of working and acting essential to satisfactory living in a complex society such as we live in. The materials of science are adaptable for use in forming habits of scientific thinking because they are objective, susceptible to quantitative measurement, and subject to law and principle. The child has a natural curiosity and interest in science materials. Such stimuli furnish continuous experiences with problem situations. The problems are solved by the association of the knowledge possessed, together with accurate interpretation of facts. Activity work in science fosters growth in ability to make adjustments.

An example of this growth is seen in John Smith who is a slow and somewhat retarded child. John became interested in making a crystal radio set. He had watched the older boys in the science workroom build such a set and had been with them when they heard sound for the first time. He was determined to build a crystal set for himself. His seeming indifference to all of his class work was quite suddenly abandoned and his teachers were delighted with his new interest. His father bought him a pair of earphones at once. The child displayed a new resourcefulness. For his coil he obtained the core from a roll of paper toweling. He obtained the necessary wire from an old radio speaker and then began his task of building a crystal set. He worked painstakingly. After many trials, he finally succeeded in putting wire, coil, and crystal in a working combination. He took it home. The next day in class he told his success story. His father had put up the aerial wire. John had helped his father connect the ground

* An address given before the CASMT Elementary Science Section Meeting at Detroit, Michigan on November 30, 1946.

wire. After the first adjustment, his radio worked! His father became so excited that he called his relatives and neighbors into the house and every one listened. John told of his father's reluctance to let him listen often enough, and how he and his father finally agreed to take turns. The child later wrote a story about his crystal radio—to the surprise of parents and teachers. He helped another child build a crystal set. He became more talkative in his classes and better adjusted in his group.

Science activity work is not exclusively for the slow and very young; for example:

A 7th grade class was confronted with the problem of learning to fly an airplane, an outgrowth of a unit on air transportation. The pupils said that they learned all about the controls, and now wanted the experience of using them. It wasn't feasible to bring a link trainer into the classroom. The size of such a model prohibited that, even if available. Nor was it possible to get an airplane to school. The class could have visited the airport but even then they couldn't get the training in flight desired. Small model airplanes in flight did little to relieve the situation. The problem was not solved that day. The next day a reserved though bright youngster exhibited some creative originality. He brought a small model of a plane which he had built. It was mounted on a vertical stick. Thin threads ran from the moveable parts of the plane to the base, which was made from an old cigar box. The controls, all simulated and accurate, were on the top of the box. The child presented a lesson in flying by talking to the class and moving the controls on the base. This was done so clearly and accurately that everyone felt that he had been a pilot that afternoon.

The incentive to build and create does not always stem from the stimulation of problem solving. Often it comes as a leisure time activity resulting from some work that has been done in the science class. An illustration of this is shown by a class watching an experiment on buoyancy. The children were amused and awed to see a bottle rising and sinking like a submarine. The principle involved was simple. The water was expelled from the bottle by means of a tube through which one blew his breath. When the tube was left open, water refilled the bottle, and the weight of water and bottle made the bottle sink. A ratio of air and water controlled the depth or buoyancy of the bottle. A few days later, a successor to our experiment was brought in. A boy had constructed a metal diver made of two tin cans with a

cork-valve system that worked with dry ice. Instead of air, the dry ice in water yielded carbon dioxide, the pressure of which expelled the water. When the diver reached the surface, the cork-valve opened. Water rushed in and sank the diver. This process continued until all the dry ice was used up. The boy enjoyed his diver and so did his friends. As an outgrowth, he is working on a toy submarine made of discarded oil cans. He has run into some difficulty with the valve system, but is determined to work it out himself. There is no doubt that his project will be successfully completed.

Functional learning is that which relates most directly to the life situations which challenge interest. In classroom teaching teachers must set learning situations that challenge interest and are purposeful as well. It is hoped that the child will pursue this interest in his leisure time and be motivated to create.

A child may bring a pebble into the classroom. He may gain a new realization as to its significance. His interest, properly inspired, may first lead him in the hobby of "rock collecting." Later his avocation may become his vocation—he may become a geologist or a mining engineer.

But it does not always follow this pattern. One child last term started collecting rocks . . . later it was mechanical toys. Quite recently he became more discriminating. He is now collecting toy motors. A few weeks ago he discovered that he could make a motor. The transition was simple. He found it less expensive and more fun to make his motors rather than buy them. Now he makes miniature motors and enjoys the prestige of knowing a great deal about them. Moreover, he is quite popular among his friends.

Sometimes a child has a need for some device to help him in his work or play. The science room seems to be the natural place to go—the laboratory in which he does his work, his experimenting, and finds the answers to his questions. The science teacher guides and directs when probelm situations arise.

Last winter a boy was confronted with a problem concerning reflection of light which he promptly brought to class. He had bought a small periscope but found that he needed a bigger one to use in his snow ball fight scheduled for Saturday. The fort he built was quite high. He took the small periscope apart to find out how it was constructed. He had all of the material with him for construction of a large one. The environment of the science workroom and the quiet encouragement of the teacher—"Why

not try it out?"—gave the boy confidence in his ability to construct a large periscope. When completed, the boy not only had a larger periscope but one which was telescopic as well. His project gave him much information about the use of mirrors in reflecting light, but the significant thing was that he had constructed a periscope that made possible Saturday's victory.

From activities in science such as the ones discussed here, there are many evidences of growth in the personalities of children. The child learns how to meet situations which arise in everyday living. He uses resourcefulness in his science work. He learns how to think and act clearly. He is concerned with problem solving. When he matures and takes his place in society, the training and experience gained through science activities help him meet life situations with a minimum of conflict.

ATOMIC ENERGY

This is the title of a new classroom film put out by the Encyclopaedia Britannica Films Inc. It aims to give the observer some idea of atomic energy and how it is released. Some of the important ideas emphasized are:

1. Identification of parts and general structure of atoms.
2. Mass-energy relationships of atomic parts.
3. Illustrative definitions of radiant energy; electronic or chemical energy; and nuclear (atomic) energy.
4. Three known forms of atomic energy release:
   a. Nuclear synthesis, as in the sun.
   b. Natural radioactivity, as in radium.
   c. Nuclear fission and chain reaction, as in the atomic bomb.
5. The distinction between atomic energy (changes in nuclei) and electronic or chemical energy (changes in electron orbits only).

Length, one reel; Price $50.00.

BOY ORNITHOLOGIST, GIRL GENETICIST WIN TOP SCIENCE HONORS

A boy from Massachusetts and a girl from Long Island, who at 16 have already attained recognition for their work in ornithology and genetics, received the top $2400 Westinghouse Grand Science Scholarships at the awards banquet closing the five-day Science Talent Institute in Washington, D. C.

They are Martin Karplus of West Newton, Massachusetts, and Vera Radoslava Demerec, of Cold Spring Harbor, New York.

Karplus, who plans to enter Harvard, major in biology and then devote his life to medical research, stands first in a class of 750 at Newton High School, Newtonville, Massachusetts.

Miss Demerec plans to enter Swarthmore to study zoology and then make a career of museum work. She is ranked among the top students in a class of 185 at Huntington High School.

WE *CAN* REMOVE THE STIGMA FROM GENERAL MATHEMATICS*

H. VERNON PRICE
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The Second Report of the Commission on Post War Plans is a landmark in the teaching of mathematics. The recommendations given for the junior high school program are, for the most part, clear-cut and commendable. Yet no report is perfect and, if I interpret this one correctly, one important idea is open to question. Before discussing this point, permit me to review briefly the part of the report which pertains to the junior high school.

The specification that "the school should guarantee functional competence in mathematics to all who can possibly achieve it"[1] is probably worthy of its listing as Thesis 1 in the report. The twenty-eight points which define "functional competence" represent the mathematical elements whose mastery is necessary by all of the children of all of the people. It is, therefore, reasonable to assume that whatever else a school may choose to offer, provision for these essentials must come first. In other words, *these elements must be incorporated into the required part of the curriculum;* that is, into the junior high school program.

The Commission is careful to point out that while the work of the seventh and eighth grades should "provide a substantial beginning in achieving functional competence"[2] it is nevertheless true that ". . . the task . . . cannot be completed for all pupils in the first eight grades. For many, this task must be continued at least through grade 9."[3] I would venture an estimate that there are *very few* pupils who can meet the requirements by the end of the eighth grade. How those schools (and there are some) which do not require some course in mathematics in grade 9 expect to meet this goal is a mystery.

Fortunately, the typical situation seems to be that mathematics courses are required *through* grade 9. In the large schools a double-track is recommended with "algebra only for those

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* Presented before the Junior High School Group, Central Association of Science and Mathematics Teachers at Detroit, November 30, 1946.

[1] "The Second Report of the Commission on Post-War Plans" *The Mathematics Teacher*, Vol. 38, No. 5, p. 196 (May 1945).

[2] *Ibid.*, p. 204.

[3] *Ibid.*, p. 206.

whose ability and future outlook indicate to their advisers that they should take it and a good course in general mathematics for the rest."[4] We should be very careful in following this suggestion, however, for a pupil who withdraws from the sequential program after a year of algebra could very easily fail to achieve functional competence. In order to avoid this it might be advisable to require election of both algebra and geometry as an alternative to general mathematics.

For the small school, three courses of procedure are suggested: offering two courses simultaneously within the same class period, providing correspondence courses, and increasing the number of courses by cycling. Under this last heading, the Commission states "Our hypothetical school might well offer algebra and general mathematics one year, geometry and general mathematics the next year, and general mathematics and another course consisting of a third semester of algebra and a semester of trigonometry in the following year. Under adequate guidance and by careful planning early in his high school career a pupil can thus get at least two years of general mathematics or even three years of sequential mathematics by the time he graduates from high school."[5] It is possible to interpret the first statement in at least two ways, but from the second statement it seems evident that the Commission is providing both general mathematics and a sequential course (probably first year algebra) in grade 9. Hence it is true that in all cases—for large and small schools alike—the recommendation is for a course in algebra for a few pupils and general mathematics for the rest. With such a program the general mathematics course retains, by default, its position as the "dumping-ground" for the poorly-equipped pupils. Yet, is any other solution practical? Certainly our experience with free election of courses has not been happy!

For several years writers have viewed with alarm the tendency for both teachers and pupils to regard general mathematics as an inferior course. The Commission also recognizes this undesirable state of affairs and echoes the belief that we must remove the halo from algebra and the stigma from general mathematics. This is to be accomplished by telling the pupils something of the nature of the two courses and by sectioning on the basis of goals as well as ability. Such a procedure is undoubtedly a step in the

[4] *Ibid.*, p. 206.
[5] *Ibid.*, p. 213.

right direction and for courses which are given on an elective basis it should give completely satisfactory results. However it is my judgment that when two courses are given at a *required* level of instruction and admission to one of these is based, even in part, on ability, *that course automatically assumes, at the very outset, a halo and the other acquires a stigma.*

Before proceeding further, let me say that I firmly believe in sectioning *within a course* on the basis of ability. The slight stigma which is then present is attached to the *pupil* and this need not concern us too much since pupils themselves have a much clearer picture of their differences than we can hope to acquire. However, when ability leads a pupil into one course rather than another, it is the *course* which assumes the stigma. I'm aware of the fact that when the selection is based on goals as well as ability the situation is somewhat alleviated. Nevertheless, when a pupil has set for himself a goal which requires training in algebra and then is shunted into general mathematics because of lack of ability, we can hardly expect him to be enthusiastic about the course.

If we agree that it is of major importance to promote respect for our courses, the issue boils down to an either-or proposition in grade 9. Algebra alone is too inflexible; as it exists today, it would provide only a few with functional competence. On the other hand, is general mathematics a satisfactory course for all pupils at this level? Certainly the answer is "no" if we consider the general mathematics which has frequently been taught. In the past twenty years the course has run the gamut from diluted algebra, through disguised social studies and business arithmetic, to an out-and-out re-hash of the seventh and eighth grade content. Each new textbook which has appeared has seemed to have different objectives. (There is some merit in this phenomenon, but it has produced confusion.) Finally, however, the Joint-Commission report[6] of 1940, our wartime experiences, and the 1945 report of the Commission on Post-War Plans have given us a definition which we can be proud to call *mathematics*. As a matter of fact, one could almost say that we have achieved a complete cycle, for with this definition of general mathematics the junior high school program is very nearly that suggested by the National Committee on Mathematical Requirements in

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[6] "The Place of Mathematics in Secondary Education," *The Fifteenth Yearbook of the National Council of Teachers of Mathematics*, Bureau of Publications, Teachers College, Columbia University, 1940.

1923—one whose content consists primarily of the fundamental parts of the sequential courses.

In this double-track age, do we dare suggest a course in general mathematics for all pupils? For at least the large schools the Commission calls such practice "unsatisfactory." Their report states "This policy delays the beginning of the study of algebra for those who plan to take the long road to leadership in science and mathematics."[7] Let us examine this statement in the light of an actual school situation.

By way of illustration, permit me to describe the program as it exists in University High School. First of all, the school is a six-year high school and our two main functions are teacher-training and experimentation. For this reason, an effort is made to keep the student body as nearly average, according to ability, as possible. Our range of talent is about the same as that found in most schools, Mathematics is required in grades 7, 8, and 9, elective thereafter. Because of the size of student body and staff, only one track is provided.

For the ten-year period prior to 1943 we taught both general mathematics and algebra in grade 9. Since that time general mathematics of the type described by the Commission has been required of all pupils. We regard the entire junior high school program, however, as a single three-year general course, very fluid in nature. Since enrollment is limited to 50 per grade, we teach two ninth grade classes sectioned according to ability. Many of the members of these classes are transfers from rural one-room schools but, because of the flexibility of the program, adjustments are easily made. Both classes follow the same course of study, although there is frequently a great difference in terms of depth and speed. If, because of this speed, it is necessary to expand the basic program, the additional work involves more advanced topics in algebra. We have yet to find, even in our best section, pupils who are dissatisfied because they are studying general mathematics rather than algebra.

For those pupils who drop out of the program at the end of this year, functional competence has, so far as possible, been provided. Those who continue with the elective program, and most pupils do, have been given a "flying start" into both algebra and geometry. Although it is beyond the realm of the junior high school, suppose we follow the progress of these pupils through the next two years of the program. Since roughly one

[7] Second Report, *op. cit.*, p. 205.

semester of algebra is included in the general mathematics sequence, grade 10 is devoted to the study of second- and third-semester algebra. Again because of the material studied in the junior high school, the pupil is able to cover in grade 11 all of the important parts of both plane and solid geometry.

Now let us return to the pupil who follows the sequential program suggested by the Commission. He will probably study first year algebra in grade 9, plane geometry in grade 10, and perhaps third semester algebra and solid geometry in grade 11. He is then *at exactly the same place as are our pupils who have studied general mathematics*. The only "delay" which is apparent is one which enables a pupil in our program to attain another year of maturity before studying formal algebra and geometry.

It is only fair to give one final quotation from the Commission report, namely, "We come now to the phase of our problem that is difficult for many teachers of mathematics—the administration of general mathematics in a way that will make it respectable and desirable. Here the attitude of the teacher is the determining factor and far too often the teacher is by training, disposed to propagandize unduly for algebra."[8] Thus it is true that a good teacher with the proper attitude can remove most of the initial prejudice against general mathematics, but it is equally true that many teachers do not possess these qualities. Why must we reckon with this variable factor when the problem itself can be eliminated at the expense of no one? Why not begin the double-track plan with the elective courses in grade 10? Most pupils at the ninth grade level have only a vague notion of what the future holds and if we encourage rather than discourage them at this crucial stage, it is possible that some may develop a real and lasting interest in the subject.

[8] *Ibid.*, p. 206.

MOSQUITO STOWAWAYS

Hundreds of thousands of Pacific island mosquitoes, some of them potential disease carriers, have been coming to this country in tires and perhaps also in shell cases and amphibious vehicles returned from combat areas by the Army and Navy.

An investigation revealed that mosquitoes were breeding heavily in fresh water contained in motor vehicle and aircraft tires which constituted a large part of the cargo. It was estimated that approximately one half of the 8,880 tires aboard contained water varying in amount from one cup to five gallons per tire and that a large proportion of these contained living mosquito larvae. It is conservatively estimated that the average tire examined contained from 20 to 30 larvae.

TEACHING DIRECTED NUMBERS

H. C. CHRISTOFFERSON
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Two fundamentally opposite points of view, as different as positive and negative numbers, dominate the teaching of mathematics. Those who hold one of these extremes feel that computational proficiency is the major objective in teaching mathematics and as a consequence their teaching consists of memorizing rules and practicing or drilling on them for proficiency. The teacher shows how problems of a type are worked or illustrates the rule of computation and the students just learn the process, with little knowledge of why the rule operates.

Those who hold the opposite point of view feel that the "why" is the important part. They feel that new computations should have meaning, that rules should be shortcuts for processes that are fully understood, and that these rules should often be discovered and expressed by the students. Computational proficiency is desirable, in fact necessary, but yet it is secondary. An appreciative understanding of the relationships involved in a new process and of the meanings expressed or implied and which are basic to the process, is the major goal of teaching. It is only by such teaching that a child learns his mathematics so that he can apply it to new situations and do creative work. Computational proficiency alone is mere training; computational proficiency based upon understanding is education.

The author of this article wrote on this same subject in SCHOOL SCIENCE AND MATHEMATICS in 1924, his first article to be published, his first year in teacher education after a few years of high school teaching and administration. The present treatment is but a review and extension of the former treatment, and a further indorsement of the point of view that an understanding of the relationships involved in mathematics is essential in mathematical education. Then too, although the ability on the part of a student to think deductively is the crowning achievement in mathematical education, most children acquire that ability gradually, and therefore much inductive teaching must precede and accompany a deductive treatment. With this point in mind, inductive thinking predominates in the following attempt to give meaning to the rules which control operations with directed numbers. Further-

more, since the number system of algebra must be an extension of the positive number system of arithmetic, the algebraic system must not confuse children in the operations of arithmetic, but rather enrich, enlarge and enliven arithmetic numbers.

The Meaning of Negative Numbers

In arithmetic a number usually means a quantity, yet there is both the ordinal and cardinal meaning of numbers. For instance, if you count 6 objects, you point to them one at a time and repeat a number.

0	0	0	0	0	0
1	2	3	4	5	6

Really the last object (0) is not 6 but the 6th object. To represent the numbers one should really have the following:

0	0	0	0	0	0	0	00	000	0000	00000	000000
						(or)					
1st	2nd	3rd	4th	5th	6th	1	2	3	4	5	6

In algebra numbers are used also for a dual purpose, but more often in the ordinal sense as a position on a scale than as a quantity. The number, plus 6 hours, may mean both the quantity (or interval 6 hours of time) and also a point on the scale of time which is 6 hours hence, much as 6 hours and 6 o'clock differ in their meanings. Similarly, $+6$ degrees may mean a point on the thermometer 1 degree above $+5°$ and 1 degree below $+7°$, then $-6°$ will likewise be a point on the scale $1°$ above $-7°$ and $1°$ below $-5°$. If the thermometer is held bottom side up, these phases would need to be changed. Likewise, if it were lying horizontally, $-6°$ may be $1°$ to the left of $-5°$ and $1°$ to the right of $-7°$. Similarly -6 miles might mean 6 miles south or east, -6 dollars might mean 6 dollars spent in which case $+6$ dollars would mean 6 dollars earned, and -6 hours could mean 6 hours ago, assuming the present to be the zero hour. In order to use directed numbers understandingly, this meaning of a number as a point on a scale, the "continuum," must be kept in mind. Consequently, some denominations would have no significant meaning. For example, $+6$ or -6 hours has a meaning on a scale, but, -6 elephants can have only a very artificial significance either on a scale or as a quantity.

Addition of Directed Numbers

Addition is a piling up of quantities. Thus $+5$ and $+3$ added

in algebra must be the same as in arithmetic when 5 and 3 are added. To make the quantities concrete, assume that +5 miles and +3 miles are to be added. The process must mean going 5 miles north, then an additional 3 miles north to a position 8 miles north. Why north? The plus sign indicates the direction, and therefore if + means north, − means south.

+5 mi.	+5 mi.	−5 mi.	−5 mi.	+5*a*	+5*a*	−5*a*	−5*a*
+3 mi.	−3 mi.	−3 mi.	+3 mi.	+3*a*	−3*a*	−3*a*	+3*a*
+8 mi.	?						

To illustrate adding +5 and −3, assume again the concrete setting of miles and these two distances added 5 mi. north and 3 mi. south would bring one to a position 2 mi. north of the original starting point, or to the position +2. To generalize this process, it seems evident that after travelling 5 mi. north, one would be *at a position* +5, then *from there*, if one travels 3 mi. south, he would *reach a position* 2 mi. north or +2. Thus it becomes evident that one can really add quantities with different signs by "piling" them together, by adding one to another along a number scale, being careful that the "additions" are in the direction indicated, as in Figure 1.

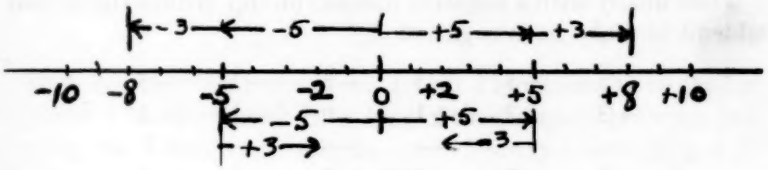

FIG. 1

Similarly, −5 and −3 can be added on the scale. Since both are in the same direction their sum is −8, but the sum of −5 and +3 would mean going 3 miles east after having gone 5 miles west and therefore would result in a position 2 miles west or −2. See Figure 1, right. Similar results can be shown with any specific meaning for the directed quantities such as adding \$+5 and \$−3, \$5 earned and \$3 spent. Finally the usual rules can be deduced with little difficulty. Usually, classes have little difficulty in adding directed numbers or in understanding the addition. Subtraction and multiplication are the more difficult operations. One more illustration for addition should be sufficient.

Addition can also be illustrated by means of adding a series of numbers to a constant addend. This can be done with specific concrete data, but can also easily be shown in the abstract deductive setting.

	+3	+3	+3	+3	+3	+3	+3	+3	+3	3+
Add:	+3	+2	+1	0	−1	−2	−3	−4	−5	−6
	6	5	4	3	2	1	0	−1	−2	−3

Since a number one less is added each time to the same +3 as we go from left to right above, the answer must be one less than before. Thus $\underline{+2}^{+3}$ must be one less than $\underline{+3}^{+3}$ also $\underline{-4}^{+3}$ must be 1 less than $\underline{-3}^{+3}$. Suppose the first addend is reduced and the second one left constant, then a negative number will appear on the top.

	+3	+2	+1	0	−1	−2	−3	−4	−5
Add:	+3	+3	+3	+3	+3	+3	+3	+3	+3
	6	5	4	3	?	?	?	?	?

Then finally with a negative number on top, reduce the second addend to make both negative.

−5	−5	−5	−5	−5	−5
+3	+2	+1	0	−1	−2
−2	−3	−4	−5	−6	−7

Since we add successively lesser numbers, the answers become successively less. $\underline{+2}^{-5}$ must be 1 less than $\underline{+3}^{-5}$ which was found to be −2. It should be evident that all the possibilities in addition have now been covered or implied, and extensions can easily be made by using concrete settings for each.

Subtraction of Directed Numbers

In arithmetic subtraction has at least three rather distinct meanings: (1) Take away, (2) Difference, and (3) Addition. One may weigh 150 lb. and lose 10 lb., then one weighs only 140 lb. One may weigh 140 lb. and his friend 120 lb. The difference be-

tween the weights is 20 lb. No one had any weight taken away. Then too, one may weigh 140 lb., but before one can be considered on the football team he must weigh 150 lb. Again we subtract, but now by thinking of adding 10 lb. to the 140 lb. to make 150 lb. The latter is closely associated with finding difference. The most fruitful meaning of subtraction in algebra is the finding of difference.

	$+5$	$+5$	-5	-5
Subtract:	$+3$	-3	-3	$+3$
	$+2$	?	?	?

The first answer has to be $+2$ to agree with arithmetic. If one point is at $+5$ and the other at $+3$, the difference between them on the scale, that is the distance from the subtrahend to the minuend is $+2$. Note the "a," Figure 2.

Then too, the difference between $+5$ and -3 is $+8$, since the distance from -3 to $+5$ on the scale is $+8$, just as the distance from $+3$ to $+5$ was only $+2$ on the scale, Figure 2, "b."

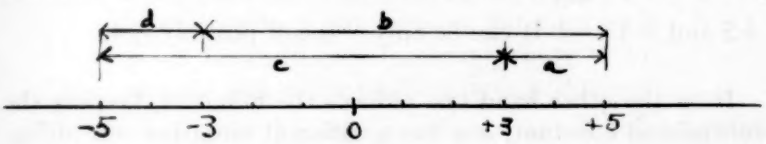

FIG. 2

How far from the home of one friend 3 blocks south to that of another 5 blocks north? How long a time elapses between two events, one 3 hours ago and the other 5 hours hence? It is $+5°$ in Cincinnati when it is $-3°$ in Chicago. What is the difference in temperature?

The answer to the last three questions could be either $+8$ or -8 depending on the direction of counting. From $+5°$ on the thermometer to $-3°$ on the same or another thermometer is $-8°$, but from $-3°$ to $+5°$ is $+8°$. How shall we determine the direction for counting? Similarly, $+5°$ and $+3°$ could have a difference of $+2°$ or $-2°$ depending on the direction of counting.

Our thinking in algebra must not confuse our thinking in

$$\begin{array}{r} 5 \\ -3 \end{array}$$

arithmetic. We know that when we subtract in arithmetic we get only 2, not -2, then we must ask how far from 3 to 5, from the subtrahend to the minuend. Therefore we must follow the

same thinking with the algebraic signed numbers. To subtract -3 from -5 the answer must be -2, ("d" figure 2) and the difference between $+3$ and -5 is -8, ("c" figure 2) or subtracting $+3$ from -5 the difference is -8.

Subtraction in algebra can also be made meaningful by thinking of the difference as an amount added to the subtrahend to make the minuend. In fact, this thought supplements and extends the difference thought above. Then too, these numbers can be made concrete by using distance, time, money, degrees, etc. The series idea is also helpful in subtraction.

	$+5$	$+5$	$+5$	$+5$	$+5$	$+5$	$+5$
Subtract:	$+3$	$+2$	$+1$	0	-1	-2	-3
	$+2$	$+3$	$+4$	$+5$	?	?	?

As one progresses to the right in the series above one subtracts 1 less each time, therefore the remainder must be 1 more each time. What then must be the answer when subtracting

$+5$ and -1? $\begin{array}{r} +5 \\ -1 \\ \hline ? \end{array}$ It can be only $+6$, not possibly $+4$.

If on the other hand one reduces the minuend, keeping the subtrahend constant, one has a different situation; the difference must decrease by 1 each time. Thus a large number can really be subtracted from a smaller one, or even 2 negative numbers subtracted.

			$+5$	$+4$	$+3$	$+2$	$+1$	
			Subtract: $+3$	$+3$	$+3$	$+3$	$+3$	
			2	1	0	-1	-2	
$+5$	$+4$	$+3$	$+2$	$+1$	0	-1	-2	-3
-3	-3	-3	-3	-3	-3	-3	-3	-3
$+8$	$+7$	$+6$	$+5$	$+4$	$+3$	$+2$	$+1$	0

The rules for subtraction of signed numbers can now come as an easy generalization discovered by many a good student.

Multiplication of Signed Numbers

Probably the most concrete and common setting in which multiplication is involved and in which quantities are used

which may have direction, is the formula, $D=rt$ or $A=rt$. Distance, rate and time can each have direction. Thus: $(+5)(+40)$ may mean traveling northward at 40 mph. for 5 hrs. The question, $(+5)(+40)=?$, may be interpreted, "If one is traveling north at 40 mph. where will one be 5 hours hence?" Then $(-5)(+40)=?$, would be equivalent to asking the question, "If one is traveling north at 40 mph., where was one 5 hours ago?" The answer is clearly, 200 miles south of the present location or -200. Similarly, $(+5)(-40)=?$, suggests that if one is traveling south at 40 mph. (-40), 5 hours hence $(+5)$, one will be 200 miles south (-200). Then too, $(-5)(-40)=?$, must mean that if one is traveling south at 40 mph. (-40), where was one 5 hours ago (-5)? The answer can sensibly be only one number, 200 miles north $(+200)$.

Summarized, we then have the following.

$(+5)\ (+40)=+200$, meaning 200 miles north
$(+5)\ (-40)=-200$, meaning 200 miles south
$(-5)\ (+40)=-200$, meaning 200 miles south
$(-5)\ (-40)=+200$, meaning 200 miles north
$tr=d$, in which each factor may be $+$ or $-$,
and the sign of the product thus determined.

The generalization becomes readily apparent, and a teacher will allow students to state it. "The product of two quantities with like signs is positive, and the product of two quantities with unlike signs is negative." Hereafter, it will be easier to use the rule than to think this all through each time one multiplies.

Suppose the $+40$ means earning \$40 per week, then -40 would mean spending \$40 per week. The first product above would then be interpreted, "If one earns \$40 per week, how much will he have earned at the end of 5 weeks $(+5)$." The last product, $(-5)(-40)$, could then be interpreted, "If one spends \$40 per week (-40), how much more or less did he have 5 weeks ago (-5)?" Clearly, the answer to both is sensibly $+200$. Similarly, for the middle two products the answer must be -200.

Division of Signed Numbers

Division is easily seen as the reverse of multiplication.

If $(+5)\ (+40)=+200$, then $(+200)/(+40)=+5$
$(+5)\ (-40)=-200$, $(-200)/(-40)=+5$

$$(-5)\ (+40) = -200, \qquad (-200)/(+40) = -5$$
$$(-5)\ (-40) = +200, \qquad (+200)/(-40) = -5$$

Note again that the quotient of 2 quantities with like signs is positive, and of 2 quantities with unlike signs is negative. Therefore, one can conclude that, "The product or quotient of 2 quantities with like signs is positive, and of 2 quantities with unlike signs is negative." Every teacher of experience will appreciate the need for noting that the rule applies only to 2 quantities. An interesting extension for fun would be to make a rule for 3 quantities, for an even number of quantities, and for an odd number, for all signs alike or for the signs different but an even number or an odd number of them negative.

Suppose we now extend the series idea to multiplication and division of directed numbers.

$(+3)\ (+2) = +6$ from arithmetic.
$(+2)\ (+2) = +4$
$(+1)\ (+2) = +2$
$(+0)\ (+2) = \ \ 0$
$(-1)\ (+2) =$? It must be -2 from the series.
$(-2)\ (+2) =$? It must be -4.
$(-3)\ (+2) =$? It must be -6

Similarly,

$(-3)\ (+2) = -6$
$(-3)\ (+1) = -3$
$(-3)\ (\ \ 0) = \ \ 0$
$(-3)\ (-1) =$? To fit in the series it must be $+3$.
$(-3)\ (-2) =$? It must be $+6$

Sufficient data all completely abstract and deductive in nature are now available for the conclusions stated previously.

There are a good many other ways of illustrating operations with directed numbers and thus making the rules seem sensible and also making it possible for students to discover and express these general truths.

Several other analyses were given by the author in his previous treatment. These will not be repeated now. Those given here have been found to be very effective and simple to understand. Ingenious teachers will perhaps wish to submit other ways of making the processes meaningful. The series analysis seems to me especially ingenious. Credit should be given to a

former student of mine for its first presentation. His name is Urban Vaccariello, one of Miami's football stars in the class of 1932. His modesty has kept him from writing it up, therefore, I present it here and give him full credit for being the first to use it, as far as I know.

In conclusion, it has been the aim of this presentation to emphasize the possibility of adding meaning to rules and thus to enrich and to enliven mathematics. Computational facility is important, but such facility based upon understanding spells functional mathematical education.

METEORITES IN NORTHERN INDIANA

Did chunks of a falling meteor burst with atom-bomb-like violence over northern Indiana, a few hundred million years ago? There is some reason to believe that they did, states Robert S. Dietz, Urbana, Ill.

A quarry near Kentland, Ind., has exposed evidence of some highly violent kind of disturbance in the St. Peter sandstone, a geological formation of great geologic age. Hitherto it has been assumed that the disruptions of the strata, elsewhere quite flat and even, had been caused by a half-smothered blow-up of a volcanic pocket far below, in some long-gone period.

However, Mr. Dietz points out, the shape and position of the dislocated conical rock masses indicates strongly that the explosion took place above, not below, the disturbed zone. And the only imaginable source for such an explosion would be meteorites, heated to the shattering-point by their passage through the earth's atmosphere, and finally plunging into the ground.

In ages after the fall, the upper levels containing the meteorite craters, as well as the meteorite fragments themselves, were eroded away, leaving only the inverted-cone "roots" in the soft sandstone. Later still, during the Ice Age, a new covering of clay and soil was deposited over the eroded surface, burying the evidence until quarrying operations brought it to light again.

THE EYE BANK FOR SIGHT RESTORATION, INC.

After a year of difficulties, and achievement in spite of these, the Eye Bank has become firmly established and is fulfilling its most important function. This is the collection and distribution of eyes, the corneas of which are to be used as material for the transplantation operation. It makes little difference if the demand for these corneas is small, or that the cases that are suitable for the operation are not numerous, or that the ophthalmic surgeons who are competent to perform the operation are few. There is no question about the need for this service. In these days of crowded hospitals and administrative difficulties, the problem of getting the recipient patient ready and the donor cornea at hand, at one and the same time, would have been one perhaps impossible of solution. This problem, however, is now solved, for all that one needs to do is to get in touch with the Eye Bank and an eye, sterile and preserved, is immediately shipped by air or messenger within a relatively few hours.

THE SCIENCE EXCURSION AS A TEACHING TECHNIQUE

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Perhaps no other area of the elementary school curriculum lends itself to the use of the excursion as well as does science. After all, science becomes important to children to the extent that it helps them to explain what is going on in the world in which they live. To a large degree the world of the child is the home and the community. That is where he has many experiences which challenge his imagination. There arise the questions which tickle his imagination. And there, too, lie the answers. They are not to be found within the four walls of the class room.

A consideration of the excursion as a technique of teaching elementary science should, it seems, deal with at least three aspects of the problem. Why use the excursion as a teaching technique? Where do you go and what do you see? How do you plan for an excursion?

WHY USE THE EXCURSION AS A TEACHING TECHNIQUE?

There are at least four reasons for the use of the excursion in the science program that are of sufficient importance to bear repetition here.

The first is a very simple and obvious one. The author has found that the rapport developed in the very informal atmosphere of the excursion pays dividends in terms of teacher-child relationships. An afternoon spent bare-footed, with trouser legs rolled up operating homemade waterwheels in a nearby brook did more to win the friendship and confidence of some fourth-graders than any other technique the author has yet discovered. That may sound naïve to the uninitiated, but you practicing elementary teachers know what it means. It is interesting to note in this respect that the only discernible difference between successful and unsuccessful teachers is the ability to establish rapport.

A second, more profound reason is implied in our modern

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child psychology. Learning takes place more readily when motivation is great. Interest in the job at hand is perhaps the most effective type of motivation. We believe that interests arise primarily out of experience. We ask ourselves, then, where does the child have his experiences? In the school, in the home, and in the community. Does it not logically follow that in addition to the school experiences we take the child out into homes and into the community to deal with those phenomena which are so frequently the source of his interests? The child feels a real need to understand his environment, and the excursion can contribute much to the satisfaction of that need.

A third reason that urges us to take advantage of the teaching resources of the community is the limitations in the kinds of science experiences which can be had in the classroom. The average elementary room leaves much to be desired as a laboratory. Many teachers are still handicapped in presenting science experiments by the lack of equipment and facilities. There is no sink, no running water, no source of heat. Even a scale or balance is lacking. In many schools the equipment consists of hand-me-downs from the high school chemistry or physics laboratory. It is poorly designed in relation to the level of manipulatory skill of the elementary school child. While the problem of the lack of materials and facilities is by no means insurmountable, it is none the less real to many elementary teachers. You may not have the glass tubing and rubber stoppers to build a model of a hot water heater, but you can take the kids over to Bobbie's house (with his mother's permission, of course) and show them the real McCoy. Even the best of equipment and the finest elementary classroom laboratory would be a poor substitute for the reality that awaits you on the excursion.

Successful teachers will attest the validity of reason number four. Excursions frequently mean transportation, and parents are often willing to furnish it. We all admit that we should get to know the parents better, but somehow we find it hard to accomplish. The excursions present valuable opportunities for getting to know them. More than that, it is surprising how grateful parents are for the chance to observe what their children are doing. Your most loyal supporters will be counted among the parents who go along on your science excursions. They will know what you are trying to do for their children, and they will approve it. Incidentally, they are as enthusiastic as kids when it comes to learning something new. Parents are valuable group

leaders on many trips, especially on those to a factory or plant where small rooms and narrow passages dictate a division of your class.

Where Do You Go and What Do You See?

The applications of science in the home and the community are so numerous that the problem of the selection of experiences appropriate to elementary school children demands the careful consideration of the teacher. There are certain guiding principles, however, which are useful in the process of selection. The excursion should not be an end in itself, but a means of enriching the on-going activities of the classroom. It is doubtful that a science program could be assured of depth and breadth on the basis of excursions alone. That is not to say, however, that the excursion should not be used as a starting point for a particular project or unit, nor as a means of stimulating interest. A visit to a nearby airport may renew and intensify the abiding interest children show in planes, and become the stimulus for further study on a new level.

It is important to realize that children do not have to understand *all* there is to be learned at the site selected. There is much that a group of third-graders can learn on a trip to a hospital or a public health office. Many teachers feel that so much technical science is applied at the public health office (dispensing immunizing serums and vaccines, making Babcock tests, presumptive test for B. Coli, etc.) that it would be far too difficult for the children. Obviously that sort of thing will be. That's not the point. There are many things that third graders can profitably learn at the public health office. Here are doctors and nurses who are working to keep us well. They make sure that our milk is pure, that cows and pigs and sheep are healthy. They see that our restaurants and soda fountains are clean. These are the people who make us stay home when we have measles or scarlet fever. Scientists are busy in our home town every day helping us to keep healthy. Those are some of the simple, and yet important understandings that might be appropriate for some third graders.

Some of the technical science observed at the health office might be pertinent for some sixth-grade children. They might well want to see just how the butterfat content of milk is determined. If they are growing bacteria on culture mèdia at school, their interest in milk plate counts becomes something

more than superficial. All this adds up to the fact that the community offers many sources of valuable learning experiences for children of all grade levels.

Some profitable experiences which will enrich a science program are visits to a water purification plant, a hospital, the board of health, or to a power plant. An excursion to observe the effects of soil erosion suggests itself. How much easier it is to teach children about the forces which are changing the surface of the earth when you take them out to see the evidences which are all about them. You can give youngsters some understanding of electricity by hooking up door bells in the classroom and playing with magnets, and at the same time take them into a home to observe these things in operation. In addition they see meters, fuzes, wiring, insulation, transformers, heating devices, and many electrical appliances with which they live every day and yet lack familiarity. An excursion to study the heating plant right in the school can add meaning to any study of heating, of fuel, of heat transfer, or insulation. The only limits to the choice of places to visit are the breadth of your science program and your ingenuity as a teacher.

Let's look at some of the things a teacher might do with a group who have decided that they wish to go afield to study soil erosion.*

The teacher has at least two courses open to him in preparing for this trip, assuming that interest in the problem has developed in the group. He can either work with and through the county agent where one is available, or plan and execute the preliminary trip by himself.

The advantages of obtaining the cooperation of a county agent are evident. Not only has he wide knowledge and experience in this field but he knows locations where examples of soil erosion and the use of conservation measures may be seen. Moreover, he usually has entree to the farms and fields where they may be observed. If the teacher relies on the assistance of a county agent on one or two excursions, he will gain knowledge and confidence, and future visits can be planned and conducted independently.

Assuming that the teacher cannot obtain assistance from a county agent or some experienced person, he will have to make

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* This is one of the fourteen trips described in the author's book, *Science Excursions into the Community*. A Handbook for Teachers of Grades Four Through Eight. Bureau of Publications, Teachers College, Columbia University.

a survey of the region armed with suggestions that have grown out of questions from class discussion and information gained from study of the material that is available. A few afternoons or a weekend spent in an exploration of the vicinity should determine the location of examples of erosion and conservation practices that will be of interest to the group. Some of the following situations may be among those for which the teacher will want to be on the alert on the exploratory trip.

1. An abandoned farm. Here the teacher will find such evidences of erosion and poor land use as gullies, poor pastures which may be compared with good pastures found elsewhere, hillsides from which most of the timber has been wantonly removed, and fallow fields gullied and sheet eroded. Weeds will be seen, generally the first vegetation that comes in to reclaim the wasted soil. The very atmosphere of the dilapidated house and outbuildings, the abandoned and rusted machinery, and the dry well paint a picture of the loss in time, money, and effort that are the result of careless farming practices.

2. A field that shows the effect of the removal of plant nutrients. A corn field, for example, will often show an area where the height of the corn is very noticeably less than most of the crop.

3. A stream that shows the cutting effect of running water against and under the banks.

4. A small dam in which can be seen the deposition of silt.

5. A muddy stream carrying land, mud, silt, and sand.

6. A cross section of soil exposed in a road cut. The rich black topsoil below the sod, the subsoil, clay, sand, gravel, and rock below may be exposed and can be examined.

7. Rock that is crumbling to form soil. This, too, may often be seen in road cuts, on the banks of streams, and in quarries.

8. Irrigation ditches.

9. Sand dunes encroaching on fertile land.

10. Washouts along the road.

11. Check dams in gullies.

12. Farms on which contour and non-contour plowing may be observed.

13. Evidences of terracing, either natural or man-made.

14. Examples of reforestation.

15. The practice of strip cropping.

16. Farm machinery used in terracing and other operations.

17. A successful farm where soil conservation methods are

being carried out. Here, in addition to some of the items already mentioned, the children may learn from the farmer about the use of fertilizer and the rotation of crops. They may see cover crops, leguminous fields, and other practices which aid in soil conservation.

Probably in no one community will the teacher find all these situations, nor would it be possible to see them all on a single trip. However, they do suggest some of the things for which the teacher can look. The interests of the children, the situations available in the community, and the time element will have to be taken into consideration in making plans for the excursion.

It will take planning to organize a path that will include the items selected, but planning will eliminate loss of time in getting from site to site. The question of trespass is involved, and the teacher should by all means obtain permission before taking the group on any private land.

Suggestions for the Excursion

If a county agent or a farmer is to act as guide, the teacher can be of assistance to him as well as to the group later by discussing with him the interests and abilities of the class in relation to what is to be seen and done.

If, on the other hand, the teacher is conducting the trip by himself, he will have to be responsible for the organization of the experiences observed. Notebooks for drawings and cameras will be of value in gathering materials for later discussion. A topographical map of the area will be particularly useful in developing the concept of contour. These may be obtained from the Director of the United States Geological Survey, Department of the Interior, Washington, D.C. It is necessary to write first for an index map of the state which gives the location and names of the areas in the state for which they are prepared. This index map may be had free of charge; the topographical map of a given quadrangle costs ten cents.

The nature of such a trip suggests the possibility of taking lunch and having a picnic somewhere in the fields or woods. This not only adds to the enjoyment of the occasion but offers opportunity for quiet discussion of what has been done and seen on the excursion.

Follow-Up Activities

Discussion.—The discussion that follows such a trip will de-

pend on the nature of what was seen, the original interests of the group, and the questions which arose in the field. The teacher may find that some of the following generalizations will be helpful in guiding the discussion so that the children may better see the relationships between these immediate experiences and others which they have had.

1. We should conserve our natural resources.
2. Man needs plants for food.
3. We must protect the land so that plants can grow well on it.
4. Man is learning to protect his soil.
5. Plants start growing from seeds, spores, roots, stems, or buds.
6. Mature plants produce parts from which young plants grow.
7. Water is necessary to life.
8. Not all plants grow best in the same type of soil.
9. Plants use light in making food.
10. The soil is one of the most important of our natural resources.

Projects.—Some of the following activities may precede or follow a survey in this area:

1. Demonstrating the weathering effect of temperature changes on rocks.
2. Showing the principle of disintegration of soil by root acids.
3. Repairing a gulley on or near the school grounds.
4. Displaying the layering effect of water on sediments.
5. Building a sand-table model of a farm showing terracing, check dams, reforestation, etc.
6. Growing plants in poor soil and in rich soil.
7. Preparing a display of facts, charts, pictures, and other material dealing with the problem of soil erosion and conservation.
8. Inviting a farmer or county agent to talk on the subject to the class.
9. Seeing the moving pictures, "The Plow that Broke the Plains," and "The River."

Other Excursions.—The teacher may find that interest in this trip will suggest one or more of the following:

1. A visit to a fertilizer plant.
2. A trip to a county fair.

3. An outing to a state park to see reforestation and methods of forest fire prevention and control.
4. A trip to study the habitat and characteristics of insect pests that attack the crops in the community.

It is obvious that what each teacher will do with his class will be determined by the age of his children, their interests at the time, and the resources available. The foregoing suggestions of what to do must be modified in each situation. This leads us to consider the problem of planning for the excursion.

How to Plan an Excursion

The *sine qua non* of any successful excursion is the preview trip made by the teacher. Going over the path, or through the plant before you take the children makes it possible for you to do several important things. You can discover what will be of particular interest to the children. The opportunity of your gaining some technical understanding is offered. The hazards, if any, can be spotted and later discussed with the class prior to the trip. If a guide is to take the children through a plant, you have the opportunity to explain to him the interests of the group, and particularly, their limited understanding of technical terms. You also can estimate how much help, if any, you will need to handle the group. Of course, knowing the amount of time required to make the trip is one of the benefits of the preview.

Planning that does not include participation by the youngsters would be poor planning indeed. They should help decide, first of all, that the trip is desirable. If the route lies in part along a highway, the question of how the group should walk (in random groups, or two by two) calls for intelligent and democratic planning on their part. It is interesting to note that the more they participate in deciding such problems, the simpler are the discipline problems of the trip. The children should discuss what equipment to take. Who is to be responsible for the camera? Do we want a jar for specimens? Should we take a (geology) hammer? This opportunity for planning by children is in itself one of the most desirable features of the excursion.

If the selected site is at some distance from the school, planning for transportation is involved. This may require a chartered bus, parents' cars, street cars, or even trains. It is important to make sure that private cars or buses are driven by licensed operators, and that insurance is carried on the vehicle. The pre-

view trip pays off here in arranging time schedules for the transportation. It is wise when parents provide their cars for a trip and participate in the excursion that they understand the teacher is responsible for the children at all times. Division of authority is never desirable.

Some teachers hesitate to take children away from the school because of the hazards that may be involved, and concern over their legal responsibility. Two legal principles are pertinent here. In the first place the teacher is never the insurer of the safety of her youngsters. That is to say, you never do assume legal responsibility that Johnie will not break his glasses on the playgrounds or that Mary will not shut her fingers in the door. Secondly, teachers like everyone else, are legally responsible for their negligence. If you fail to provide any supervision for Johnie on the playground, or if you repeatedly fail to report the defective door stop, you are legally responsible to Johnie's parents and Mary's parents. The teacher who makes the preview trip, discusses hazards and desirable conduct on the excursion with the children and who uses reasonable care and judgment need never worry about legal responsibilities. The author has made many excursions with elementary school children and has never had an unpleasant experience.

Planning becomes easier when teachers within a school or school system cooperate in keeping records of the trips. An excursion file in a central location is an invaluable means of pooling information. A 3×5 card filled out after each trip will make it easier for you next time, and for one of your colleagues the first time. The following is a sample of the type of information that might be recorded:

Excursion—To Acme Milk Pasteurizing Plant.

Location—582 Benson Avenue.

Permission For Visit Granted By: J. L. Barnes, Superintendent.

Telephone—Br 4-1727

Directions—Via Ocean Road trolley to 14th Street. Walk two blocks east on Benson. 10 cents round trip.

Experiences—Saw trains that bring the milk from country, storage tanks, pasteurizing, bottling, icing, loading on trucks. Children given free milk and cookies. Interesting talk given on source of milk, methods of shipping, testing. Time (from school to school), 1 hour 35 minutes.

Teacher—Miss Carter.
Date—10–6–39.
Grade—5.

In summation, it seems clear that the science excursion is dictated by the best thinking in educational psychology and philosophy. It is an old technique but a profitable one that happily changes the rhythm of day to day instruction. It is within the ken of every elementary teacher since the materials for instruction are myriad in all communities. A little time spent in exploring your community will suggest many sources of vital science excursions you can enjoy with your children. The benefits are accumulative both for you and for the youngsters. The first trip adds to your confidence and your store of knowledge. You will approach each subsequent excursion with an anticipation born of assurance. What you can do depends on the interests and maturity of the children, the knowledge possessed by you and your guides, and the sites which are selected. Careful planning will help you to make the most of the teaching resources of your community. The excursion is the spice of the science program. Try it.

AMERICAN INSTITUTE OF PHYSICS

Reorganization of the American Institute of Physics and plans for a new semi-popular journal devoted to the fast-growing science and its relation to society have been announced by the Institute.

Effective immediately the 7000 members of the five societies—The American Physical Society, The Optical Society of America, Incorporated, the Acoustical Society of America, Incorporated, The American Association of Physics Teachers, and The Society of Rheology—will become members of the Institute. Heretofore the Institute has been an organization of these five Member Societies without any individual memberships. Provision is also made for associate membership in the Institute, open to others interested in physics.

"No change is made in the organization, functions, and activities of the five societies," the announcement, published in The Review of Scientific Instruments said. "Rather the way is opened for all persons interested in physics to play individually a greater part in the affairs of physics where these are of common concern to all.

"The new journal for which initial financing is now being sought will contain news about physicists, their meetings, their work and other activities, and about similar features in related fields; information about the action of governmental and other non-physics agencies affecting physics; articles and letters presenting the views of physicists on problems of general importance; references to current literature in physics; book reviews, etc."

HOW GOOD ARE OUR TESTS?

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How good are our eyes? Obviously the answer involves the use to which the eyes are to be put. Good eyes, for the American Indian, required skill in seeing what is on the far horizon. For the dyer of cloth, eyes certainly must not be color-blind. For the biologist, eyes must correctly distinguish between the very minute forms of matter even though his microscope may greatly extend the range of that skill. The sugar chemist needs eyes sensitive to slight differences of light and shade as he uses his polarimeter.

In an analogous fashion the question, "How good are our tests?" may be explored. Do we, by their use, wish to look to the far horizon of our student's future in terms of his skill and satisfaction in making postulates and drawing inferences—in science? Do we want to learn if he is mentally allergic to generalization and the associated ability to think in terms of abstractions i.e. symbolism? Do we wish to find if he is sensitive to the "light and shades" of word meanings as applied to his field of interest? Do we wish to determine to what extent he is aware of the limitations of the tools of his laboratory procedures?

As pointed out in a previous paper[1] a good test for any one of the above purposes is not equally good for other purposes. Cataloging a test as "good" waits upon a definition of the purpose of its use. In the end, perhaps, we wish to know how "good" our *students* are and wish the test used to help us arrive at such an estimate. But in probing for that, the alert teacher will want to impose the added requirement that she wishes to know. "How good he is for WHAT?"

Various plans have been used to find the answer to the question, "For what are tests to be used?" One plan,[2] by direct appeal to the teachers, sought to find in just what way they expected their course in college chemistry to change their students. Another attempt[3] was directed at what college text books in chemistry plan for the chemistry course to do to students. When

[1] How Shall We Test? SCHOOL SCIENCE AND MATHEMATICS, 47: 322, April, 1947.

[2] Smith, O. M., Accepted Objectives in Teaching General College Chemistry, *J. Chem. Educ.* 12: 180–183 April 1935.

[3] Hendricks, B. Clifford, and Handorf, B. H., Examination Practice in General College Chemistry, *J. Chem. Educ.* 15: 176–179. April 1938.

these two studies had their outcomes checked against examinations actually given by college teachers of chemistry, some disturbing disagreements became apparent. While fifty-two per cent of some 200 teachers of college chemistry expressed a desire that their students acquire some ability "to formulate and test hypotheses" not a single one of 7107 examination test items used by teachers of college chemistry was an item for that purpose. Likewise, forty-five per cent of the 200 teachers said they expected their course in chemistry to improve their students' skill and develop proper habits in the use of the library. However, no reference was found to this part of their program in the 7107 examination items inventoried. Other desired outcomes for college chemistry, as approved by eighty or more per cent of these 200 teachers of college chemistry were: 1, skill in stating laws and principles; 2, ability to apply laws and principles to practical situations; and 3, some facility in drawing conclusions from data. The inventory of the 7107 items found but twenty-three per cent of them including a call for the statement of laws or principles, ninety per cent had items on applications of laws and principles; however, but nineteen per cent made any attempt to pose data for which inferences were required. Perhaps high school teachers make their tests mesh more consistently with their proposed course aims than did these college teachers. If not it is apparent that their tests are not "good" to the extent that they leave, what teachers consider, important purposes of the course entirely untouched by their subject-matter census. In a sense, such examinations are not "good" because of poor sampling.

Previous reference[1] has been made to the improvement of the sampling by increasing the number of items in the test as a whole. The 7107 items used in the preceding paragraph were taken from forty-six different examinations. These sets had a median of 120 items per set but some had as few as thirty-one items and one had the maximum number of 334 items. With as few as thirty-one items an acceptable sampling of subject matter or personality traits might be tested if in compiling the test a proper distribution within the field was carefully made. On the other hand, the longer test, with its 334 items, might be *"not good"* if its items were unbalanced in their distribution or at fault in other respects.

Another respect in which "goodness" of examinations may vary is in the quality of the items in the test. In characterizing

test items it has been said,[4] "There are two very important considerations in any selection of test items. The first is *item validity* or discriminating power and the second is *item difficulty*." The second of these test-item qualities has ever been watched by both pupils and teacher. Teachers are too often moved to modify "hardness" by "scaling upward" and by promises of "an easier one next time." However, an easy examination is not a "good" examination. For if the examination is to serve in distinguishing, with certainty, which are the best students and which are the least able students in the course its items must have very few perfect scores. To give the surest indication of students of varying abilities the scores upon the test must be widely scattered over the scale of achievement. An item that has a median score of five, upon a ten point scale, is certainly more serviceable for the teacher's purposes than one having twenty-five per cent of its scores as high as ten. In brief "good" examinations are not easy examinations.

The test technician labels the relation of the test outcome to subject-matter or personality objectives as its *validity*. Do scores on student answers to a given test arrange the students in a rank-order which may be correctly considered an index of their achievement in line with the aims of the course? If so, to that extent, the test is a "*good*" test. To the extent that it fails to set up an order in agreement with progress toward the course's aims it is a "poor" test.

Do test items actually used by teachers show great variations in this quality called validity? To get information in answer to this query examination answer sheets from 1300 students were analyzed[5] for validity by comparing median scores, made by the upper twenty-seven per cent of the 1300 students, with the median scores made by the lower twenty-seven per cent of that group. Obviously if the difference is greatly in favor of the upper rating group that question is useful as a means of identifying such upper group. That sort of test item is said to have high validity. There are two other results possible from this comparison and they are: the median of one group may not be any higher or lower than that on the other or the median of the low group may actually be higher than that on the upper group. Items which come out with no difference between the groups

[4] Flanagan, John C., General Considerations in the Selection of Test Items, *J. Educ. Psychology*, 29, 674 (1939)

[5] Hendricks, B. Clifford, Examination Practice in General Chemistry. Quality of Questions, *J. Chem. Educ.* 21, 85–86. Feb. 1944.

are said to have no validity; they are "waste timber" for test building purposes. Items that bring answers from low group students that are better than from the high group ones are said to be inversions and are not considered "good" items for test building.

A census of 108 items, selected from the 7107 previously mentioned, were found[5] to be classifiable as shown in the table below.

QUALITY OF GENERAL COLLEGE CHEMISTRY EXAMINATIONS

Kinds of questions	*Per cent of the 108 items*
Too easy	23
Low validity	13
No validity (No differentiation)	7
Inversion (Poor student making the better grade)	1
Total faulty items	44
Usable but not "good" items	16
"Good" items	40

The above table gives information on college examinations for teachers who were interested enough in better examinations to submit their answer sheets for the analysis. Their examination questions were probably better than those of their colleagues who were not interested in "finding out." Even so the examination questions of the more alert teachers are only forty per cent "*good*." Readers of this would, no doubt, join with the author in wondering what the answer to the question may be for our high school teachers.

The excellence of examination items may also be rated in terms of their *reliability*. At least two factors are involved in this quality of the items: is the item so worded that it will always have the same meaning to the student even whough he is asked to answer it at times widely separated from each other, and is its answer sufficiently objective that the reader will not change his "model answer" between scoring sessions?

The "good" examination will also receive approval from both student and teacher if it has what are called practical qualities i.e. its time and reading demands are reasonable, its scoring can be made reasonably objective and its administration does not require the proctor to interrupt with oral supplementary directions as the test session progresses.

How may we know if our test is "good"?

First, make sure the test properly and adequately samples the skills, understandings and personality traits our teaching aims have sought to achieve.

Second, critically edit each item, after student answers have revealed their *validities*, looking for those with no validity or low validity. "Good" items do not have such deficiencies.

Third, the student answers sheets will help spot the "easy ones" which consume time without adding to the usefulness of the test.

Fourth, the "good" test has items that are *reliable* so that the score on it is "reproducible" by any given student.

POTASSIUM PHTHALIMIDE CONTAINING NITROGEN 15

A pound and a half of potassium phthalimide containing the "tracer" isotope Nitrogen 15 and believed to be the largest quantity of an organic compound containing an isotope ever prepared was shipped recently from Rochester to Columbia University in New York.

Produced in Eastman Kodak's Synthetic Organic Research Laboratory, the rare compound will be used by physiologists to find out what happens to amino acids in the human body. The acids are products of the body's break-down of proteins in foods.

According to Dr. C. F. H. Allen, assistant superintendent of the Kodak laboratory, under whose direction the work was carried out, Columbia scientists will convert the potassium phthalimide into special amino acids containing the isotopic nitrogen.

Because its atomic weight is greater than that of ordinary nitrogen, the Nitrogen 15 will serve as a "tracer element" to tag the acids.

These, in turn, will be synthesized and administered to test animals. Medical scientists, by tracing the acids and Nitrogen 15 in the animal organism, will add to their knowledge of this aspect of the chemistry of the body.

A NEW YOUNG AMERICA TEACHING FILM FOR ELEMENTARY SCHOOL SCIENCE CLASSES

What Makes Day and Night?—a new teaching film for the elementary school science program designed to demonstrate and teach the reasons for the alternation of day and night. Specifically correlated with the science program for Grades 3 and 4. The film shows Jane and Jim asking their father what makes day and night, where the sun goes at night, whether all the world has daylight at the same time, and other similar questions. Using a globe and a flashlight, Mr. Lewis shows the children how the alternation of day and night is caused by the rotation of the earth about its axis. He also demonstrates to them that the sun can only shine on one-half of the earth at a time, so that while half the world is experiencing night the other half is experiencing day

Running time: 8 minutes (½ reel). Sale price: $30.00, 16 mm., black & white. Teacher's Guide included.

For preview prints and further information, address Young America Films, Inc., 18 East 41st Street, New York 17, N. Y., or your local Young America dealer.

FILMING FOR YOUR SCIENCE CLASSES*

ELLA M. CLARK
Northwestern High School, Detroit, Michigan

Many teachers now-a-days are equipped with movie-kodak outfits, so that filming for their science classes is a great possibility. The field is wide— not only in science, but geography, travel, athletics and the like. You as a science teacher know so well what you need in films to supplement and vivify the text. With right planning and a bit of knowledge of good photography you can achieve results that are excellent and pleasing, as well as instructive.

Your students are more vitally interested in the films of your making and experiences than in the commercial ones. They also will take great interest in helping to film these and in finding the material for such use. They can help plan the film and even aid in assembling the material. Through their trips to locate material and by looking up data concerning the topic, they will gain much interest and knowledge of science first hand.

THE MATERIALS

Films: You can use Super X and XX films, both indoors and out, though the kodachrome (colored) is by far the more satisfactory, as well as more expensive. My students have repeatedly told me how much more worth-while the colored pictures were than the usual commercial films. That's a conservative statement of their opinion.

Either Type A, for indoor filming, or the regular kodachrome for outdoor work is fine. Type A *with a filter* can also be used outdoors, and I have even used the regular (daytime) kodachrome with artificial light and *no filter* with interesting results, for some subjects.

Apparatus Useful: Beside your kodak outfit, it is very helpful to have a titler, a 3 inch telephoto lens, a pair of small tweezers, a proquil pen for fine printing and drawing, 2 or 3 sizes of a child's printing set, a large drawing board (18×24 inches), colored pencils, chalk, and the Nupastel sticks.

One can make a small box-like compartment that will hold an electric bulb. Over the top, the lid should have an opening cov-

* Read before the Biology Section of the Central Association of Science and Mathematics Teachers at Detroit, November 29, 1946.

ered with a piece of frosted glass. Through the sides and front of box there should be a few scattered small holes to allow for circulation of air and the cooling of the space in box. This box is useful for the filming of such objects that need to have the light penetrate them, such as the developing embryo in hen's egg. By placing contents out of egg shell on a large petri dish, and setting dish over the light in box, one can film even the heart beating.

Also helpful is a block of wood, heavy enough to stand on its edge, as a background. Oak is good. Size, about 7 inches square and 1 inch thick. Cover this on top with a soft material, such as the strips of flat cork you have in laboratory. This allows pinning of specimens to it, or standing as a background when using the titler for filming objects.

Another device you can make that will prove useful is a light wood frame (about 22×24 inches, strips the width of $1\frac{1}{4}$ inches and $\frac{1}{4}$ inch thick). To this you can thumbtack a piece of semi-transparent material (preferably peach color) like that used in shade making. This frame is then used as a shade in front of the electric bulb (100 W) but in back of the object to be filmed. It lets light shine through object, in a soft diffused way, yet prevents the form of the bulb showing. This screen is of use when you need to film crystal-like objects whose beauty and structure show when light passes through them. With the ordinary filming method they would be dark and solid looking. Of course in filming these you still need the usual photobulb in front and falling on the object at the proper distance.

A child's printing set is handy for printing of your titles.

The Filming Process

You need first to be thoroughly familiar with the subject matter desired. Think through carefully all steps so that there will be continuity, a good sequence to your theme. Select with care and thought the various scenes.

Then ascertain where the material can be located. Your students can take a hand in this. Determine whether the material will show best, out-of-doors, in a natural surrounding, or indoors arranged to be more effective. When filming objects out-of-doors you need to look the situation over before hand to determine which time of day is most effective and from what angle will give the best background and effect. Of course there are some shots—just lucky ones that are taken on the spur of the moment

—you just ran into an unusual event or situation that will work into some film either in process or later.

One can shoot *against the sun* (this is contrary to the usual rule in photography) if the lens is shaded in some way, or the sun blocked out by a tall object, such as a tree or spire on building. When students are to be in the picture, you can avoid their squinting and distortion of face by placing them in the open shade of some building or trees with the sun even coming from in back of students and so with your kodak shooting into the sun. Just shade the lens in some way. The lighting effect is desirable, soft and diffused.

Much care should be taken as to the source of your light, for the various angles of light, either artificial or natural, give widely differing effects. I have had some very striking effects by placing the light *below* the object and slanting up to it from in front. This will need to be determined by the individual before the filming of each subject.

Shooting from moving cars or trains is possible. It is best to be in the front of auto, but one can also film from side windows, either open or shut, or from the rear window. *Be Sure Your Lens is Above the Ledge of Window,* not merely that you can see all in the finder. *Hold Kodak Steady.* Set camera speed at 32 not the usual 16. *Give It More Light;* if Weston read for F11, use F 8.

Backgrounds: For use indoors, one finds pieces of silk or rayon very pleasing, light blue prefered, light green, possibly a light, soft yellow, and occasionally a dark color in contrast to a light subject. This can be brown, or green, even blue. I use 3 sizes of cloth—a small one, about 12×14 inches; medium 18×25 inches; and large, the width of the cloth (usually 39 inches)×1½ yds. The small piece is used over the oak block of wood, the medium sized fastened to the drawing board, while the large one is tacked up to the wall in back of your object, cloth either straight or in easy folds as desired.

The wall can also be used for background if the paper is not of a large pattern, or the wall finish glossy or too vivid a color. Keep to the pastel shades—cream, buff, light blue.

Your outdoor backgrounds—be sure to watch these. The sky with clouds forms the best. Otherwise don't have the background filled with details. Instead have a massed solid effect unless you are filming a scene. Have this background far enough back so that it is out of focus thus producing a soft uniform

effect. Be sure the bushes if used for a background do not have openings in them letting the light through, as this will give light spots in your picture.

Camera Lens: Mostly you will be using the regular lens for your indoor shots, usually at 2, 3, or 6 ft. focus. Outdoors, all depends on the material to be filmed. Usually the regular lens again at 6 ft. (or closer) to get more details, but often at 10 ft. and even 25.

The *Telephoto Lens* comes into play frequently in outdoor shots where you have objects too high up to get a good shot otherwise, as blooms on maple trees; or when filming birds or animals that you can't get near enough to without disturbing their activities. You can film through your kitchen window at small birds (Titmice) on your feeding shelf and have them appear good size and coloring.

Your Titler: It is a great help in filming very small objects both indoors and out. For the titler frame can be placed over a bee in action on a flower, or over the disc flowers of a composite head, giving much detail and very pleasing shots. Indoors, the titler is spendid help in the filming of minute objects making possible the showing of details. Such as the hairy stigma, parts of the bean seed, antenna of moth, head of fly or a fish scale. In filming the parts of a soaked bean seed use a blue background and a bit of black paper placed behind the plumule against the white of the cotyledon.

Title Making

Titles add much to the interpretation of your films, as well as to the interest. It is fascinating work. Few people realize or even think about the mechanism of the titles; they are just pleasing or clever ones to them. But nevertheless Titles Do Add to the Film.

For Materials to Use: You can get the out-dated sample books of wall-paper from your dealers, either the small books or, better still, the large. This affords a variety of uses. You can buy rolls of some pleasing wall-paper, either single or double.

The pictures and the colored paper from Xmas greeting cards and those of other occasions supply very desirable material. The white backs of these cards are of use for tryouts of a title, or as shopping list paper.

It is highly advisable to catalogue, *by topics*, all your pictures and material, and file them in folders. Then when you wish title

or background material of a certain theme you do not need to wade through all.

Postal cards of flowers and animals or scenes again afford rich material.

Travel folders often give pictures (even colored) that are just right for your film scene, as a title.

The use of macaroon letters (a soup making product) over a background (either a picture or wall paper) form a very interesting way for the lettering of your titles. These letters can be either left white, or painted various colors, or blackened.

You can make yourself a set of small ($1\frac{1}{4}$ inches high) block letters out of balsa wood which you paint black or any color. These can be fixed so that they will stand on the table, against a background. The shadows cast by such letters are often interesting. You can make them "do things" on the screen, come in and out of the picture one at a time, or be knocked down, either standing in a straight row or curved. This is "the how" of these *Spread Out (or Knock Down) Title.*

1. Have a pleasing background,—natural wood wall paper on the large drawing board placed against the wall.
2. For the foreground on which the letters stand use another sheet of this wood wall paper, or a colored cloth (inconspicuous). Be sure that the foreground extends well under the background.
3. Now set up the title on the foreground, with All Letters of Title Complete as, for example, Indian Corn.
4. With Your Kodak *Upside Down* (held thus, and steady while filming) take a snap of the title. Be Sure to Read Title Through *Twice* while running the kodak to ensure enough length of film in the finished product.

   Also if filming on a 3 or 6 ft. focus be sure to parallax in the *upper part* of the finder as the kodak is held in this reverse position. This means that the letters of your title must be seen by you as you run the kodak, in the *upper* part of the finder.
5. Now, take a *series* of shots,—kodak still held upside down—thus:

   Knock down one letter at a time (filming each), with a stick, either from behind the letter or from the side, starting with the rear end of the title, i.e. the last letter. As in our example, knock or push down first n, then o, then r, then c, etc. until all letters in the title are down. Snap the letter in the process of being pushed down, Kodak Upside Down.

   Instead of using the stick and knocking down the letters I've found it more pleasing to merely remove each letter between shots while the kodak was *not running.*

   Take each shot, the title with one less letter removed from the *rear,* with kodak upside down. Time of exposure *very short* on each shot, lever just down and up, or possibly as you count 1-2-3, quickly.
6. Now take a short snap (1-2-3) of the table or place where the letters stood, *free of* any letters, kodak still upside down, short exposure.
7. When the film comes back from the processing, splice in to your reel *reversing the film.*

Modifications of the Above Method

1. Form your title of colored bean seeds, or black muskmelon seeds (very good) laid on a pleasing background (sheet of wall paper).
2. Take title as all set up, kodak upside down, parallax in upper part of finder.
3. Then have some one jiggle the corner of the paper (out of lens range) while the film is running (kodak upside down), short count 1-2-3-4 till seeds are all in confusion.
4. Film the plain background (short time 1-2-3).
5. In splicing reverse the film.

You can have an electric fan blow the letters away. Fan should not be too near seeds.

Or: Build up your title on the sands of a seashore with shells or stones.
Film step 2 of the seed method just described, in same manner.
Then film a big wave coming in and washing title all away (kodak upside down yet).
Last film the shore plain—title all gone (short time, 1-2-3).

Other Methods for Titling

1. Your own drawings at the side of title or scattered throughout adds much to the title. You can do this on large sheets of paper. The wood wall paper is especially attractive. You can also use the large *cream* colored sheets of the largest scrap book. Use either your regular lens at 2 ft., or 3 ft.; or the telephoto lens at a focus of $3\frac{3}{4}$ ft. to 5 ft. for filming.

   You can draw minutely on the small sheets for use in the titler.
2. Oftentimes the picture you wish to use is not big enough for use with the regular lens even at 2 ft. focus, yet it is too big to use in the titler space. You can build up the margin of the picture after placing it on a drawing paper sheet, or the back of a large sheet of wall paper. To do this use crayons, pastel chalk, drawing pencil, or India Ink, and continue the design in the picture extending it well around the margin. Thus extend the foreground, build up more sky at the top, or on the side imitate whatever is at the edge of your picture. You often do not need much extension and it is not hard to do although it may sound so.
3. The easiest and quickest titles to make are those with the titler, *typing* out the title on a pleasing background. You must be sure not to extend the typing beyond the space indicated by the mask that comes with your titler. In typing these titles you should have a new ribbon on machine and type each line over twice to be sure the letters are black enough. If using an old ribbon, type over 3 or even 4 times.
4. *Swing Titles.* These are very desirable.

   Make a frame out of 2 thicknesses of cardboard that will fit inside the frame of your titler. Fasten together with Scotch tape.

   Size of cardboard $3\frac{3}{8} \times 4\frac{3}{8}$ inches.

   Cut a hole in center $2\frac{3}{8} \times 3\frac{3}{8}$ inches.

   Make a revolving frame out of the cardboard, to hold the titles.

   Size of cardboard $2\frac{3}{8} \times 3\frac{3}{8}$ inches.

   Put 8 photo album corners, one on each corner of this revolving frame.

   Cut a piece of plain wood wall paper to fit into these corners (on one side of the revolving frame) size $2\frac{1}{2} \times 3\frac{1}{16}$ inches.

   All titles to be used with this should be same size as this, so as to slip in and out of the holder (revolving frame).

To fasten the revolving frame into the outside frame: insert a piece of knitting needle (or similar wire) about 5 inches long through a hole in the middle of the top frame strip, going between the two layers of cardboard, and on through the center of the revolving part (again between the two thicknesses of carboard), down through the center part of the lower margin of the outside frame. Adhesive tape will help hold the rod to frame yet let it revolve. Also wind the handle with tape so that you can turn the handle.

A similar frame can be made that will revolve up and down instead of sideways. However the first one is more pleasing.

To Work this Device:

Slip the frame into the frame on the titler so that the turning handle is upward.

Center title (now in the revolving frame) with the guide supplied with your titler outfit.

Clamp the frame to the titler frame by using a clothespin at the top left, or side margin, so that the frame is held firm yet will allow the revolving of the center.

Place a plain background on the block of wood (the small blue cloth is good) and stand block behind the titler easel far enough to allow the easy swinging of revolving frame.

Start the plain side of revolving part about halfway crosswise the frame space.

While running the kodak, with a light bulb held over the lens and shining on the frame, turn the title slowly until it is straight in frame facing the lens.

Read the title twice through while running the kodak.

Then continue turning the title, slowly, till it disappears.

In splicing, put your picture in next and it will appear like turning a page.

Continue, taking the next title, by placing it on the back of the revolving frame and continue the turning to bring the second title to the front. Repeat as often as desired.

Making of Diagrams or Route Maps

One often needs to bring into play the use of diagrams or maps in bringing out the structure of certain objects, or to show the route followed in getting to some location, or material.

Draw your diagram; color various parts; then for a pointer use these: the long handle of a small paint brush, the pointed end of a steel seeker or even a knitting needle. If these are too short you can often fasten on an addition. Use with the regular lens at 2 ft. focus. The seeker can be used while filming with the titler. These pointers can be moved around over the

diagram. The pointers can be used on objects just as well as on diagrams.

Another effective pointer is made out of a long narrow strip of stiff paper whose end has been pointed and black-tipped. Print the label on the strip end. Use small printing if pointer is to be used in titler title, larger print for use with the regular lens at 2 ft.

Printed labels can also be fastened on or near the object to be filmed. India ink is best, very black print is needed.

Making the Lines Travel on Your Route Maps (or Diagrams)

1. Get an outline map of the territory in which you wish to show route, size 11×16 inches is good.
2. Color in the various areas.
3. At the starting point pin on a small label of the town, or point.
4. Put the map on the background board, against the wall. Use two light bulbs (#2 photobulb and 100 W electric), one on each side about 2 ft. from the map.
5. Shoot this, a short run, say lever of kodak down and right up, or as you count 1-2-3 rapidly.
6. Next, put on 1 or 2 bars, using India Ink or colors, in the direction of the travel.
7. Snap this, short, 1-2-3 counts.
8. Now, put on 2 more bars and repeat operation, *as often as the route is long.*
9. At special points along the line, pin on a new label, reading it (in filming) *twice through.*

Sections of the map prove better in filming than to take in the entire map. You can film from a 2 foot focus then and get more details and the route line will show plainer. For the entire map you will need to use a 4 ft. focus.

For a Super X film with use of 2 bulbs at a 2 ft. distance from map, use F 11 for an average light colored map.

For Kodachrome film with artificial light and *no filters* use 1 stop, more light, usually, or F 8, even F 5.6.

Type A film is best for the filming of colored maps.

Using the Telephoto Lens for Filming Postals or Pictures

There are sometimes places you can't get shots of, such as in the Detroit Tunnel. But you can use a colored postal of it for a scene in your film.

Again, you may have a colored picture you desire greatly to use for a title or otherwise. But it is too big to use in the titler and yet too small to film with the regular lens even at 2 feet.

Here is where the telephoto (3 inch) lens comes in play. But be sure *to parallax a good deal.*

Here's how: place the card or picture on the drawing board background. Build up the margins if necessary as previously described. Or use a mat around the postal card. You can focus as close as $3\frac{3}{4}$ feet with this lens, but you must parallax much below the 3 ft. marker in your finder. Thus: have the top edge of the title as you wish it seen on the screen, *below* a level that is half way between the 3 ft. marker on the finder and the lower edger of the finder. The bottom of your title, or picture will be far below the lower edge of the finder, yet it will be visible on screen. Have the title *well over on the left side* of the finder. The first letter in the title (if it is placed toward the edge of title) can be clear at the edge of the finder, yet there will be plenty of margin on the left in the finished picture. Otherwise the margin on the two sides will be unbalanced.

To show some of these points four reels were shown: Bird Embryo, Summer, Pollination and Germination.

PHYSICS CANDIDATES IN THE COLLEGES

An unprecedented spurt in college enrollment of prospective physicists indicates that the severe shortage in this type of scientific personnel will be relieved much earlier than previously estimated, Dr. Marsh W. White, professor of physics, Pennsylvania State College, said at a joint meeting of the American Physical Society and the American Association of Physics Teachers at Columbia University.

In the next three years the number of students graduating with physics majors will average about 73 per cent above the pre-war figure, Dr. White said, basing his estimate on a survey of all educational institutions graduating students with physics majors.

Candidates for Ph.D. degrees in physics in 1946–47 number 180 to 200, the survey showed. This is close to the figure for 1940–41, the last normal prewar year, Dr. White said. About 900 other doctoral candidates are currently enrolled.

The survey shows that about 700 students expect to receive master's degrees this year and about 1000 are enrolled for this degree in later years.

"The data indicate that the shortage of physicists is likely to be filled much earlier than was previously estimated," Dr. White said.

The survey showed that less than 400 colleges in the United States will graduate students with bachelor's degrees in physics this year. The number offering graduate work in physics at the doctorate level is only about 60.

Facts when combined with ideas constitute the greatest force in the world. They are greater than armaments, greater than finance, greater than science, business and law because they are the common denominator of all of them.—Carl W. Ackerman.

NOTES FROM A MATHEMATICS CLASSROOM

JOSEPH A. NYBERG
Hyde Park High School, Chicago

132. Making 154 Correct Predictions. The problem of the blacksmith who received 1¢ for driving the first nail in a horse shoe, 2¢ for the second nail, 4¢ for the next, and so forth is often used to illustrate the powers of 2. A similar problem, which I find more entertaining, is:

Suppose that when the baseball season starts you were to receive a letter telling whether your home team would win or lose the first game. And suppose for 154 days of the baseball season you received such letters predicting the winner each day. Do you think this could be possible?

After as much discussion as time permits, I explain.

Let me start with a list of 2048 persons. On the first day I send a postcard to 1024 of them saying that the home team will win, and to the other 1024 I send a card saying the home team will lose. Suppose the home team wins. Then I divide into two equal groups the names of those who received the correct prediction. To 512 I send a prediction that the home team will win, and to 512 I send the opposite prediction. On the third day I divide into two equal parts the names of those who received the correct prediction. And so forth. Eventually there will be one person of the original 2048 who has received 12 correct predictions. And by starting with a sufficiently large number on the first day I could have a person who has received 154 correct predictions.

How many letters would I need to mail the first day?

133. The Diameter of a Sphere. A previous NOTE (Feb. 1947) discussed a problem (the parabola through three points) that involved more than one of the compartments into which high school mathematics is unavoidably divided. Another good problem that combines many different units is that of finding the diameter of a sphere. Texts on solid geometry present the usual geometric method involving a ruler and compass construction. Deriving a formula for the diameter involves some good review of plane geometry, some algebraic work, and, if the computations are actually performed, some logarithmic work.

The class has a spherical blackboard about 18 in. in diameter. With compasses we draw a small circle on the sphere and measure the spread of the compasses. Call this length p. On the small

circle three points, A, B, and C, are marked, and the distances between them measured. Let a, b, and c be the sides of triangle ABC. From these measurements we propose to find the diameter of the sphere.

First we must find the area of ΔABC using

$$S=\sqrt{s(a-a)(s-b)(s-c)}$$

and then find an altitude from $S=\frac{1}{2}bh$.

Next, we prove an exercise from plane geometry: the product of two sides of a triangle equals the altitude to the third side times the diameter of the circumscribed circle, or $2R=ac/h$, or

$$R=\frac{abc}{4S}$$

a formula known to all students of trigonometry.

Consider next a right triangle DEF, with the right angle at E, and the altitude EG to the hypotenuse. If EG has been made equal to R, and DE made equal to p, then DF is the required diameter of the sphere. From the similar triangles,

$$d=\frac{p^2}{\sqrt{p^2-R^2}}.$$

We thus have a succession of formulas for finding d.

Spherometers, the mechanical gadgets that measure the diameters of spherical solids, use $a=b=c$, and measure the distance e between the plane of the small circle and its pole. A good exercise is: Derive a formula for d in terms of a and e.

Further interest in the work can be created by having various pupils draw small circles on the sphere, make the measurements, and compare the results.

134. Radical Equations. There are no verbal problems in the elementary field that lead to equations like

$$2x-\sqrt{x+1}=8 \qquad \sqrt{x+3}-\sqrt{2-x}=3$$

and I cannot recall any problems of trigonometry or solid geometry that lead to such equations. Nevertheless, such equations should not be omitted from the third semester of algebra. It is always a great surprise to the pupils to learn that they can do all the algebraic work correctly and do all the arithmetic correctly and still the supposed root does not check in the equation. Also, as in the second equation above,

there may exist no number that satisfies some statements that *look* like genuine equations.

This is a good place in which to discuss some related matters about equations and problems.

Squaring both members of an equation may introduce what we call extraneous roots.

Using a poor multiplier when clearing an equation of fractions may introduce a new root.

A number that makes a denominator zero is not a root.

An equation may have a root which is not a correct answer to the problem which leads to the equation. For example, find three consecutive integers whose sum is 37.

This discussion may also consider how mathematics proves that certain things are impossible, such as trisecting an angle with ruler and compasses, because the equations cannot be satisfied.

One more item should be included. Equations like

$$x\sqrt{3}+x=\sqrt{2} \qquad \frac{2x}{1-x^2}=\sqrt{3}$$

in which the unknown does not appear in a radicand are not solved by squaring both members. The second of these equations, and others like it, should be solved in class for the benefit of those who may enroll in trigonometry classes. The equation is used to find $\tan \frac{1}{2}A$ from $\tan A$.

135. Mathematicians, Codes, Wars. Teachers of geometry have long used *The Gold Bug* by Poe as an example of reasoning applied to the unravelling of a cryptogram. Hence I wish to call attention to the book *Secret and Urgent, The Story of Codes and Ciphers* by Fletcher Pratt (Blue Ribbon Books, Garden City, N. Y., and only $1). I suggest also that mathematics teachers mention the book to teachers of history in their schools. I had always believed that wars were won by the general who was more clever than his opponent or had more soldiers or more guns. After reading this book I am inclined to think that wars are won by the party that has the best mathematical staff to solve the enemy's codes. Just to create some interest in this book I mention some facts that histories never taught me:

In 1864 the northern armies had complete knowledge of the Confederate's codes, and the latter were never able to break (that is, solve) the codes of the enemy.

The Russians won the Russo-Turkish War through a knowledge of the enemy's code. And the Germans won the battle at

Tannenburg in the First World War, because they knew the Russian code.

The innocence of Dreyfuss was proved by solving a code.

At the battle of Jellico the English knew the position of the German fleet (but could not notify the English commanders because of the weather).

The end of the submarine sinkings in November 1917 was due to the solving of a German code.

136. Significant Figures. Textbooks usually define significant figures by examples. Thus 267 and 26.7 and 2.67 each have three significant figures; and 93,000,000 has two significant figures if the number has been rounded off to the nearest million. It would have three such figures if the number had been rounded off to the nearest 100,000. Writing 2.0 means that we have expressed a number to the nearest tenth and hence the zero is significant. There are three significant figures in 2.00 since we have written the number in this way to indicate that it is correct to the nearest hundredth.

After giving these examples it would be interesting to ask the pupils to define significant figures. This is, of course, an exercise in English composition since many persons are unable to express in words an idea that may be clear to them through examples. The following definition is from Shuster and Bedford's *Field Work in Mathematics*.

"When every figure in a number except the last is exactly correct and the error in the last is less than one half unit, all the figures have real meaning and are called significant figures."

My choice of words for this definition is:

A number has n significant figures if all but the last are correct and the error in the last one is half the unit that it indicates. Zeros to the right of the decimal point and between it and the first non-zero figure are not considered.

To this definition we need to add that zeros are significant or not according to whether they fulfill the definition. If a number ends in zeros, as 3000, we cannot tell how many of the zeros are significant unless we are furnished with additional information telling whether this number expresses a measurement to the nearest 100 or nearest 10 or nearest unit.

To explain the phrase "the error in the last figure is half the unit that it indicates" questions should be asked like:

What is the possible error in 239? Ans. .5.

What is the possible error in .034? Ans. .0005.

PROBLEM DEPARTMENT

CONDUCTED BY G. H. JAMISON
State Teachers College, Kirkville, Mo.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution or proposed problem sent to the Editor should have the author's name introducing the problem or solution *as on the following pages.*

The editor of the department desires to serve its readers by making it interesting and helpful to them. Address suggestions and problems to G. H. Jamison, State Teachers College, Kirksville, Missouri.

SOLUTIONS AND PROBLEMS

Note. Persons sending in solutions and submitting problems for solutions should observe the following instructions.

1. Drawings in India ink should be on a separate page from the solution.

2. Give the solution to the problem which you propose if you have one and also the source and any known references to it.

3. In general when several solutions are correct, the one submitted in the best form will be used.

LATE SOLUTIONS

2012. *Helen M. Scott, Baltimore, Md.*

2014. *J. M. Makey, Wilmore, Ky.*

2017. *Proposed by W. Nicholson, Chicago, Ill.*

Show that the pth power of an integer n, is equal to the sum of n consecutive integers of the form $4K \pm 1$, K an integer.

Solution by Francis L Miksa, Aurora, Ill.

The sum of n consecutive integers of form $4K \pm 1$ is given by,

$$\sum_{i=0}^{i=n} 4(K+i)+1=n(4K+2n-1) \tag{1}$$

$$\sum_{i=0}^{i=n} 4(K+i)-1=n(4K+2n-3). \tag{2}$$

Setting (1) and (2) equal to pth power of integer n we have,

$$n^p=n(4K+2n-1) \tag{3}$$

$$n^p=n(4K+2n-3) \tag{4}$$

or

$$n^{p-1}=4K+2n-1 \tag{5}$$

$$n^{p-1}=4K+2n-3. \tag{6}$$

If K is to be an integer then we should have

$$n^{p-1} \equiv 2n-1 \pmod 4 \tag{7}$$

$$n^{p-1} \equiv 2n-3 \pmod 4. \tag{8}$$

From this it follows that n cannot be an even number, for let us assume $n=2N$ then (7) and (8) become

$$(2N)^{p-1} \equiv -1 \pmod 4 \tag{9}$$

$$(2N)^{p-1} \equiv -3 \pmod 4. \tag{10}$$

Now $(2N)^{p-1}$ will always be even for any value of N or p and hence $(2N)^{p-1}+1$ and $(2N)^{p-1}+3$ will always be odd, and hence cannot be divisible by 4.

Now let n be odd, say $(2N+1)$ then (7) and (8) become

$$(2N+1)^{p-1} \equiv (4N+2)-1 \pmod 4 \tag{11}$$

$$(2N+1)^{p-1} \equiv 4N+2)-3 \pmod 4 \tag{12}$$

reduces to

$$(2N+1)^{p-1} \equiv 1 \pmod 4 \tag{13}$$

$$(2N+1)^{p-1} \equiv -1 \pmod 4. \tag{14}$$

Expanding by binomial theorem and noting that every term of expansion except the last two is divisible by 4, (13) and (14) become

$$(2N)^{p-1} \equiv 0 \pmod 4 \tag{15}$$

$$(2N)^{p-1}+2 \equiv 0 \pmod 4. \tag{16}$$

There are four possible combinations for (15) and (16)

(1)	(2)	(3)	(4)
N even	N even	N odd	N odd
p odd	p even	p odd	p even

It can be readily verified that congruence (15) will hold for (1), (2), (3) but not for (4). And congruence (16) will hold for (4) but not for (1), (2), (3).

Hence in either case, *for odd n only*, an integer K can be found that will satisfy equations (3) and (4) and allow us to find n consecutive integers whose sum will equal the pth power of n.

2018. *Proposed by Norman Anning, University of Michigan.*

Solve:

$$A+B+C=180^\circ$$

$$14 \cos A = 22 \cos B = 77 \cos C.$$

Solution by the Proposer

From $A+B+C=180^\circ$, we have

$$-\cos C = \cos (180^\circ - C) = \cos (A+B) = \cos A \cos B - \sin A \sin B,$$

$$\cos C + \cos A \cos B = \sin A \sin B$$

This, squared and reduced, leads to

$$\cos^2 A + \cos^2 B + \cos^2 C + 2 \cos A \cos B \cos C = 1. \tag{1}$$

(This relation can be traced to Lacroix, 1798.)

If we write $14 \cos A = 22 \cos B = 77 \cos C = 154x$, we shall have $\cos A = 11x$, $\cos B = 7x$, $\cos C = 2x$. When these values have been substituted, (1) becomes

$$308x^3+174x_2-1=0, \qquad (2)$$

$$(14x-1)(22x^2+14x+1)=0,$$

$$x_1=(1/14), \qquad x_2=\frac{-7+\sqrt{27}}{22}, \qquad x_3=\frac{-7-\sqrt{27}}{22}.$$

The rational root, $x_1=1/14$, leads to the set of acute angles:

$$A_1=38°12.8', \qquad B_1=60°, \qquad C_1=81°47.2'.$$

The root, $x_2=-0.081993$, leads to the set:

$$A_2=154°24.7', \qquad B_2=125°01.6', \qquad C_2=-99°26.3'.$$

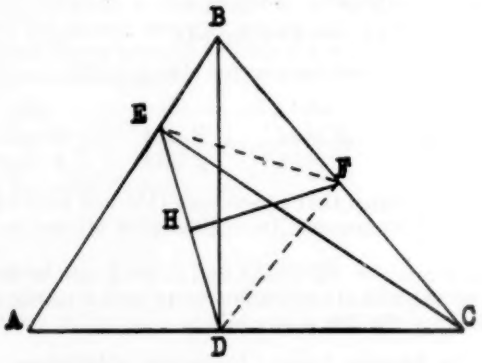
The root $x_3=-0.554371$, leads to a set of complex values for A, B, C. They can be found by anyone who must have them.

Solutions were also offered by V. C. Bailey, Evansville, Ind.; Helen M. Scott, Baltimore, Md.; Francis L. Miksa, Aurora, Ill.; Hazel S. Wilson, Annapolis, Md.; M. Kirk, Philadelphia.

2019. *Proposed by V. C. Bailey, Delaware, Ohio.*

The perpendicular bisector of the line joining the feet of two altitudes of a triangle bisects the third side of the triangle.

Solution by Sister Mary Paula, Notre Dame, of Maryland, Baltimore, Md.



Given: $BD \perp AC$; and $CE \perp AB$.

Let F be the midpoint of BC.

Draw DF and EF.

DF and EF then are medians of right triangles BDC and CEB respectively.

Therefore $DF=\frac{1}{2}BC$ and $EF=\frac{1}{2}BC$.

Therefore $DF=EF$, and since all points equidistant from the ends of a line lie in the perpendicular bisector of the line, the perpendicular bisector of the ED passes through F, the midpoint of BC.

Another Solution by Aaron Buchman, Buffalo, N. Y.

It is at once evident that (a) the feet of two altitudes of a triangle and the ends of the third side are concyclic, and (b) the third side is the diameter of this circle.

Since the line joining the feet of the two altitudes is a chord in this circle, the perpendicular bisector of this chord will pass through the center of the circle, and therefore, the midpoint of the third side.

Solutions were also offered by A. W. Gordon, Chilton, Wis.; Margaret Joseph, Milwaukee, Wis.; Norman Anning, University of Michigan; Walter R. Warne, also Mrs. Walter R. Warne, Dayton, Ohio; Hazel S. Wilson, Annapolis, Md.; Helen M. Scott, Baltimore, Md.; W. R. Hunter, Cranbrook, B. C.; and the proposer.

2020. *Proposed by V. C. Bailey, Delaware, Ohio.*

In triangle ABC, if a, b, c, and h_b are consecutive integers with $a>b>c$, find a, b, c, and h_b.

Solution by Hazel S. Wilson, Annapolis, Md.

Let the given quantities be represented as follows:

$$h_b=x-2, \qquad c=x-1 \qquad b=x, \qquad a=x+1.$$

Applying Hero's formula for the area of a triangle we have

$$s=\frac{3x}{2}, \qquad s-a=\frac{x}{2}+1, \qquad s-b=\frac{x}{2}, \qquad s-c=-\frac{x}{2}-1.$$

$$A=\sqrt{\frac{3x}{2}\left(\frac{x}{2}+1\right)\left(\frac{x}{2}\right)\left(\frac{x}{2}-1\right)}$$

$$=\sqrt{\frac{3x^2}{4}+\frac{x^2-4}{4}}=\frac{x}{4}\sqrt{3(x^2-4)}\ .$$

Also,

$$A=\tfrac{1}{2}x(x-2)=\frac{x^2-2x}{2}\ .$$

Then

$$\frac{x}{4}\sqrt{3(x^2-4)}=\frac{x^2-2x}{2}\ .$$

The solution of this equation, is $x=0$, 2, 14. Only $x=14$ is applicable. This gives $a=15$, $b=14$, $c=13$ and $h=12$.

Solutions were also offered by Francis L. Miksa, Aurora, Ill.; Aaron Buchman, Buffalo, N. Y.; Norman Anning, University of Michigan; Helen M. Scott; Baltimore, Md.; Walter R. Warne, also Mrs. Warne, Dayton, Ohio; Edythe M. Soner, Syracuse, N. Y.; Virgene Watson, Arlington Heights, Ill. and the proposer.

2021. *Proposed by Philip Heber, New York City.*

A man is given 100 coins totaling \$43.05 to buy stationary as follows: a' erasers at $1¢$ each, b' rulers at $5¢$, c' notebooks at $10¢$, d compasses at $25¢$, e' pencils at $50¢$, and f pens at \$1.00. How many items of each can be bought?

Solution by Francis L Miksa, Aurora, Ill.

We can at once set up two equations.

$$a+b+c+d+e+f=100. \tag{1}$$

$$a+5b+10c+25d+50e+100f=4305. \tag{2}$$

From (2) it is evident that 'a' must be a multiple of 5.

$$b+2c+5d+10e+20f=861-a/5. \tag{3}$$

Subtract (1) from (3)

$$9e+19f=761+4a/5-c-4d. \tag{4}$$

By giving a the value of 5, 10 etc. and $c=1$, 2, etc. and d likewise we can get many solutions, in fact they may run into many thousands, because the writer worked out the values of $a=5$ and $c=1$ to 6 with all the corresponding values of d for those cases and got over 1000 solutions. Here are a few of them:

a	b	c	d	e	f	a	vb	c	d	e	f
5	13	1	1	76	4	5	41	2	11	6	35
5	9	3	1	80	2	5	19	3	1	61	11
5	7	4	1	82	1	5	17	4	1	63	10
5	13	6	1	67	8	5	23	6	1	48	17

Since the proposer did not ask for all possible solutions the above will suffice.

Solutions were also offered by W. R. Smith, Passe a Grille Beach, Fla.; W. R. Hunter, Cranbrook, B. C.; Edila Ganza, Brownsville, Texas.

2022. *Proposed by L. Jacobus, Kinderhook, N. Y.*

The sides of a triangle are 5, 19, and 21 in length. Show that the angles are in arithmetic progression and that the common difference is arc cos 13/19

Solution by V. C. Bailey, Evansville College, Evansville, Indiana.

Let

$$a=5, \quad b=19, \quad c=21.$$

Then

$$A<B<C.$$

By the Law of Cosines

$$\cos A=37/38, \quad \cos B=19/38, \quad \cos C=-11/38.$$
$$\cos (B-A)=13/19, \quad \cos (C-B)=13/19.$$

Solutions were also offered by Norman Anning, University of Michigan; Walter R. Warne, also Mrs. W. R. Warne, Dayton, Ohio; Hazel S. Wilson, Annapolis, Md.; Francis L. Miksa, Aurora, Ill.; Helen M. Scott, Baltimore, Md.; Aaron Buchman, Buffalo, N. Y.

HIGH SCHOOL HONOR ROLL

The Editor will be very happy to make special mention of high school classes, clubs, or individual students who offer solutions to problems submitted in this department. Teachers are urged to report to the Editor such solutions.

2019. *Dick Allen, Fermie, B. C.*

1995. *Charles W. Beatty, John Murphy, Joseph Baraniewicz, Catholic H. S., Philadelphia.*

2006. *Robert F. Golden, Richard J. Monahan, James Finnegan, Catholic H. S., Philadelphia; Dolores Lund, Mason City, Ia.*

2019. *Orville Schaeffer, Caroline Garnier, Paul Mueller, Arthur Brownell, Norman Ashcraft, Arlington Heights (Twp. H.S.) Ill.*

2019. *Ronald Hansen, Des Plaines, Ill.; Melvin N. A. Peterson, Northbrook, Ill.*

2021. *Frank H. Chasteler, Hammond, Ind.*

PROBLEMS FOR SOLUTION

2029. *Proposed by Lillian F. Hayden, Troy, N. Y.*

If in triangle ABC, $a^4+b^4+c^4=2c^2(a^2+b^2)$, find angle C.

2030. *Proposed by James S. Frost, Willard, N. Y.*

Solve:

$$x(y+z)=a$$
$$y(x+z)=b$$
$$z(x+y)=c$$

2031. *Proposed by Orville F. Barcus, Philadelphia, Pa.*

Derive a formula to show that there are 33 pairs of consecutive primes between the number 11 and 1000 inclusive. Also find the pairs.

2032. *Proposed by Susan Warne, St. Johns, Newfoundland.*

Show that the series

$$\frac{1}{2}+\frac{1}{1+\sqrt{2}}+\frac{1}{1+\sqrt{3}}+\cdots$$

is divergent.

2033. *Proposed by Norman Anning, Ann Arbor, Mich.*

If a and n are positive integers, prove that $(\sqrt{a}+\sqrt{a+1})^n$ is the sum of the square roots of two consecutive positive integers.

2034. *Proposed by Hugo Brandt, Chicago.*

If A and C are the centers of two squares erected on opposite sides of a quadrilateral, and if $AC=2d$ find the maximum area of the quadrilateral

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BOOKS AND PAMPHLETS RECEIVED

ELECTRONS (+ AND −), PROTONS, PHOTONS, NEUTRONS, MESOTRONS, AND COSMIC RAYS, by Robert Andrews Millikan, Formerly *Professor of Physics, the University of Chicago; Director, Norman Bridge Laboratory of Physics, California Institute of Technology.* Revised Edition 1947. Cloth. Pages x+642. 12.5×18.5 cm. The University of Chicago Press, 5750 Ellis Avenue, Chicago 37, Ill. Price $6.00.

ESSENTIAL BUSINESS MATHEMATICS, by Llewellyn R. Snyder, *San Francisco Junior College and School of Accounting, Golden Gate College.* Cloth. Pages xii+434. 15×23 cm. 1947. McGraw-Hill Book Company, Inc., 330 W. 42nd Street, New York 18, N. Y. Price $2.75.

PRACTICAL BIOLOGY, by Edwin F. Sanders, *Washington Park High School, Racine, Wisconsin.* Cloth. Pages viii+618. 15×23 cm. 1947. D. Van Nostrand Company, Inc., 250 Fourth Avenue, New York 3, N. Y. Price $3.00.

ESSENTIALS OF COLLEGE ALGEBRA AND MATHEMATICS OF INVESTMENT, by William L. Hart, *Professor of Mathematics, University of Minnesota.* Third Edition. Cloth. Pages vi+304+126. 14×21.5 cm. 1946. D. C. Heath and Company, 285 Columbus Avenue, Boston 16, Mass. Price $4.75.

ARITHMETIC, by Clifford B. Upton and Kenneth G. Fuller. Grade Six. Cloth. Pages vii+312+xix. 13×20.5 cm. 1946. American Book Company, 88 Lexington Avenue, New York 16, N. Y. Price $1.20.

ARITHMETIC, by Clifford B. Upton and Kenneth G. Fuller. Grade Seven. Cloth. Pages vii+328. 13×20.5 cm. 1947. American Book Company, 88 Lexington Avenue, New York 16, N. Y. Price $1.24.

FUNDAMENTALS OF SOLID GEOMETRY, by Joseph A. Nyberg, *Instructor in Mathematics, Hyde Park High School, Chicago, Illinois.* Cloth. Pages vi+267. 12.5×18 cm. 1947. American Book Company, 88 Lexington Avenue, New York 16, N. Y. Price $1.72.

THE THEORY OF MATHEMATICAL MACHINES, by Francis J. Murray, *Associate Professor of Mathematics, Columbia University.* Paper. Pages viii+118. 21×28 cm. 1947. King's Crown Press, 1145 Amsterdam Avenue, New York 27, N. Y. Price $3.00.

THE RADIO AMATEUR'S HANDBOOK, by the Headquarters Staff of the American Radio Relay League. Twenty-fourth Edition. Paper. 632 pages. 16×24.5 cm. 1947. The American Radio Relay League, Inc., West Hartford 7, Conn. Price $1.25 in United States; $2.00 elsewhere.

SEMIMICRO LABORATORY EXERCISES IN HIGH SCHOOL CHEMISTRY, by Fred T. Weisbruch, M.S., *Head of the Science Department, William Cullen McBride High School, St. Louis, Missouri.* Paper. Pages iii+269. 20.5×27 cm. 1946. D. C. Heath and Company, 285 Columbus Avenue, Boston 16, Mass. Price $1.48.

PRACTICAL NURSING. An Analysis of the Practical Nurse Occupation with Suggestions for the Organization of Training Programs. Paper. Pages vi+144. 22.5×29 cm. Superintendent of Documents, Washington 25, D. C. Price 55 cents.

ANIMAL HIDE AND SEEK, by Dahlov Ipcar. Paper over Boards. 40 pages. 20.5×25 cm. 1947. William R. Scott, Inc., 72 Fifth Avenue, New York 11, N. Y. Price $1.50.

ANYWHERE IN THE WORLD. The Story of Plant and Animal Adaptation, by Irma E. Webber. Paper over Boards. 64 pages. 16.5×19 cm. 1947. William R. Scott, Inc., 72 Fifth Avenue, New York 11, N. Y. Price $1.50.

ARITHMETIC. Teaching Fractions in the Upper Elementary Grades, by H. Van Engen, *Iowa State Teachers College, Cedar Falls, Iowa.* Volume 1, No. 3, December, 1946. Paper. 27 pages. 15.5×23 cm. Bureau of Extension Service, Iowa State Teachers College, Cedar Falls, Iowa. Price 10 cents.

INSTITUTE OF INTERNATIONAL EDUCATION. Twenty-Seventh Annual Report of the Director, Stephen Duggan. Paper. 98 pages. 15×23 cm. October 1, 1946. Institute of International Education, Inc., 2 West 45th Street, New York, N. Y.

A CAREER IN LIFE INSURANCE SALES AND SERVICE, Prepared by Educational Division. Paper. 16 pages 13×21 cm. Institute of Life Insurance, 60 East 42nd Street, New York 17, N. Y.

A CAREER AS ACTUARY. Paper. 8 pages. 11.5×18 cm. 1946. The Actuarial Society of America, Room 912, 393 Seventh Avenue, New York 1, N. Y.

PRELIMINARY ACTUARIAL EXAMINATIONS. Paper. 26 pages. The Actuarial Society of America, New York 1, N. Y.

BOOK REVIEWS

CHARLES DARWIN AND THE VOYAGE OF THE BEAGLE, Edited with an Introduction by Nora Barlow. Cloth. Pages 279. 14×21 cm. 1946. The Philosophical Library, Inc., 15 East 40 Street, New York, N. Y. Price $3.75.

This book, a product of one of Charles Darwin's grand-daughters, concerns the famous five-year exploring expedition of the great scientist while a young man serving as naturalist on the British naval hydrographic ship *Beagle*, 1831–1836. Following 39 pages of introductory material, the author presents in full thirty-nine of Darwin's letters (six of which were written in England before sailing) to members of his family, with explanatory notes by her. Many of the letters are here published for the first time. About half of the book consists of extracts from 24 of the pocket note books carried by Darwin on his travels. There are several pages of illustrations of persons and scenes in South America, where most of the exploring was done. A folded map giving the track of the cruise of the *Beagle* and a map of South America showing the route of Darwin's inland expeditions are included.

The letters and note books are all the more revealing since they were not written for publication. Their interest lies chiefly in the insight they give us into Darwin's character and intellect. Readers who have already developed an interest in Darwin's mind and labors in science, especially in evolution, from reading his *Journal of Researches*, *Diary of the Voyage of H.M.S. Beagle*, and *Autobiography*, will find a valuable supplement in this book. Those who have not read any of the above named books will no doubt be stimulated to do so by the reading of this volume.

The book is clearly printed on paper of a substantial grade and is neatly bound in cloth. There is a Glossary of scientific names and Spanish nouns used in the book and an Index.

EDWARD C. COLIN
Chicago Teachers College
Chicago, Illinois

THE AMAZING ELECTRON, by James J. Shannon, S.J., *Head of the Department of Physics, St. Louis University*. Cloth. Pages xii+248. 13.5×21.5 cm. 1946. The Bruce Publishing Company, 540 N. Milwaukee St., Milwaukee 1, Wis. Price $4.00.

Here is an excellent brief account of the study of the electron from Perrin to the atomic bomb. It is told in the clearest possible language, almost without mathematics, chemical symbols, or other characters that hide the meaning from the layman. It gives only the essentials, and these are told with a minimum of technical language. The nature of the electron

is briefly explained; its mass, charge, speed, and relation to the nucleus are given in simple manner and the method used in determining each is briefly explained. Many diagrams are given and discussed to clear up the scientific details to the untrained mind. This is a book for the physics teacher whose course work in modern physics has been meager; it is for other science teachers who have not had courses in modern physics; it is for the educated layman who wants to know the necessary steps taken by the physicist that led him to the atomic bomb. It gives the essential first steps that have led to the development of great industries such as radio and television, to the use of x-rays and electron microscopes in solving the problems of health and disease, to the applications of photoelectric cells in thousands of ways for the benefit of man and the promotion of industry, to the studies in cosmic research and atomic energy with applications and beneficial results still ahead.

G. W. W.

ELECTRICAL ENGINEERING, by Fred H. Pumphrey *Educational Service Division, General Electric Company*. Cloth. Pages xii+369. 14.5×23 cm. 1946. Prentice-Hall, Inc., 70 Fifth Avenue, New York 11, N. Y. Price $5.35.

This book is another in the Electrical Engineering Series of the publishers, which is filling a long felt need in the intermediate field between the fundamental college physics and the more advanced specialized college engineering texts. Although the author presupposes a knowledge of physics, he reviews all of the fundamental principles and theory that are related to the engineering aspects of electricity.

The text is designated for the non-engineering student who finds that he must have a background knowledge of the apparatus and machinery that are normally the specialty of the electrical engineer. The principles are presented in an interesting yet authoritative manner that should appeal to the non-technical student who has any desire to learn the field. The explanations and illustrations are sufficiently clear to make the text valuable for self education of those finding a need for a general knowledge of this field.

Of special interest is the treatment of alternating current circuits and machinery which are in such common use but which require more time for elementary comprehension than can be given in the college physics course. Many technically trained people in fields other than electrical engineering find that they must use both alternating current equipment as well as increasingly common electronic devices. The principles of the electron tube and allied fundamental circuits are presented in a survey form.

The last half of the text is devoted to typical apparatus and applications that one might find in common use. Considerable attention is given to methods of automatic controls in industry.

H. R. VOORHEES
Chicago City College, Herzl Branch

Gas analyzer, which makes use of infra-red or heat rays, can detect one part of carbon monoxide or carbon dioxide in 50,000 parts of air. It can make a continuous, automatic analysis of any gas capable of absorbing infra-red rays and measure its concentration in a mixture.